CHAPTER 1

Set basics: Your first barbecue

All the technical aspects of filmmaking—film stocks, cameras, lighting, sound, effects—involve a myriad of small details that, taken as a whole, seem impossibly complex. As with any craft, to become a master requires years of experience and exposure to many different situations. It has been my experience, however, that no single piece of equipment, procedure, or technique is really complicated; there is no one thing that cannot be explained and understood in less than 10 minutes. Making movies is the artful application of millions of relatively simple details. This book helps with some of those details, describing procedures that save time and promote safety, clarifying aspects of the craft that are confusing and often misunderstood, and supplying a wealth of information about the hundreds of gadgets of which lighting technicians are so fond.

Starting with the basics, we begin with a summary of the role of the lighting crew on a film set.

JOB DESCRIPTIONS OF THE LIGHTING CREW

The electric, grip, and camera departments fall under the direction of the *director of photography* (DP). The *gaffer* and *key grip* are the DP's lieutenants. The gaffer is the head of the electric department, in charge of the lighting crew. The gaffer's crew consists of a *best boy electric* and the set electricians.

Director of photography

Q: How many directors does it take to screw in a lightbulb?
A: One; no, two... no, no one.

The DP is the director's right hand; he or she is the one who helps the director make all the hard decisions. It is the DP's responsibility to create on film what the director has envisioned for each scene; to evoke the proper time, place, and atmosphere by means of lighting; and to help choose camera angles and camera movement that will be most effective in telling the story and covering the scene. He or she designs the lighting, balancing realism against the dramatic potential of more stylized effects, as called for by the script and the director. It is often incumbent on the DP to photograph particular actors with special care in order to maintain their screen persona. The DP must maintain proper screen direction (a responsibility shared with the script supervisor) and lighting continuity between setups so the film can be edited seamlessly. The DP has a say in the design and color of the sets and the wardrobe and in the selection of locations. The DP works closely with the *assistant director* (AD) to schedule scenes at the right time of day for the best light. The DP usually shoots tests prior to the beginning of photography. He or she may experiment with various lighting

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effects, with different gel colors, with film stocks and special lab processes or different filter combinations, looking for a combination of effects that accomplishes the special requirements of the script. The DP may also conduct his or her own research prior to production to ensure the authenticity of a period look and to inspire ideas for the cinematography.

The DP holds a position of immense responsibility, creatively and financially. The producer and director both depend on the DP to achieve photographic excellence within the constraints of the production's budget and schedule. The DP always faces conflicts in fulfilling the needs of the script, director, schedule, and budget and meeting his or her own aspirations for the photography. The lighting crew fights the DP's battles on the front lines. Their ability to light the set quickly and efficiently directly affects the DP's ability to produce great work and do it on a schedule.

Gaffer

Q: How many gaffers does it take to screw in a lightbulb?
A: How many do we have on the truck?

The gaffer is the chief lighting technician (CLT), the head of the lighting department. He or she works directly with the DP to implement the lighting plan and help achieve the photographic look of the film. The DP, the gaffer, and the key grip attend preproduction meetings together and scout the locations where filming is to take place. They discuss the DP's approach to each scene and determine what lighting preparations and equipment are required. Gaffers are problem solvers. They often have to design a special rig, fabricate a gadget, or implement technology in some idiosyncratic way to give the DP something he or she is looking for, or to provide time efficiency during production. It falls to the gaffer and key grip to research possible solutions, source the materials, design all the specifics, and if necessary, present the plan to the DP and to the production manager for approval, and then see the plan to fruition.

On the set, the gaffer is responsible for the execution of the lighting scheme and the organization and operation of the lighting crew. The DP and the gaffer discuss the lighting. Typically, when talking about the actor's lighting, the DP may specify the placement of each fixture to accomplish a particular effect. Sometimes the DP may leave it to the gaffer to translate general ideas into specifics. The DP may express the goals in terms of the motivating sources of light for the scene, the mood, and the f-stop at which to shoot. The gaffer then instructs the crew and sees to the exact placement and focus of each light to accomplish the DP's instructions. Typically, once the gaffer has executed the lighting, the DP will "sweeten" it to taste, with a few adjustments.

The gaffer must have a very strong eye for lighting and a solid knowledge of which lights to use to create any desired effect. As the lighting starts to come together, the gaffer functions as a second pair of eyes for the DP, always on the lookout for problems—inadequate light, overexposure, hot spots, ugly shadows, and so on. Together, the DP and gaffer look for opportunities to make the scene look more interesting. A first-rate gaffer has a critical eye for the balance of light and shade, the modeling of facial features, and the separation of foreground from middle ground and background. The gaffer, carrying light meters on a belt, often stands next to the DP at the camera to view and measure the light hitting the subject and to consult with the DP on issues of fill ratio and balance of exposure.

A very important part of the gaffer's job is organizing and running the lighting operations. He or she must constantly be cycling through the many tasks at hand, pushing forward the progress of each project, keeping an eye on the performance of the lighting crew, thinking ahead so that the electricians will have power and lights readily at hand for subsequent shots, and forestalling delay.

The gaffer should never have to leave the immediate area in which the action is being filmed. He or she must rely on the crew to be close at hand to make lighting adjustments and fetch equipment when it is needed. Once the lighting is complete, the grips and electricians clear the set, but remain nearby, in case a tweak is called for between takes. Because the lighting crew is always under time pressure, an electrician who stays near the action, listens, and thinks ahead can do a lot to help the gaffer and DP win their daily battle against time.

Best boy electric

The best boy electric is the gaffer's chief assistant. He or she is in charge of personnel and equipment for the electrical department—a vital role in the smooth running of the lighting crew. One of the best boy's duties is scouting locations with the gaffer, making scouting notes to help the gaffer compile the list of equipment needed. The best boy supervises the load-in (loading electrical equipment into the truck at the rental house before the first day of production), organizes the equipment and supplies in the truck for easy access, makes sure that no equipment gets lost at each location, keeps track of damage, makes repairs, performs maintenance, and supervises the load-out after the last day of production. The best boy keeps track of gels and expendables, and coordinates equipment orders, returns, subrentals, and special orders with the production department and transportation departments as necessary. The best boy is in charge of hiring and laying off extra electricians when needed. The best boy supervises the electrical crew's startup paperwork and time cards. When there is no rigging gaffer hired, the best boy may also plan the routing of the feeder cable and supervise the distribution of electrical power to the lights.

Most important, the best boy is the emissary of the electrical department, communicating and coordinating with other departments, with the fire marshal, and with rental houses and other equipment suppliers. A best boy who maintains good relations with each department can get cooperation when it is needed. For example, when the best boy needs to put a light on the roof of a building, the locations team must make the necessary contacts to secure that spot. When the best boy needs some extra equipment delivered quickly, his or her relationships with the transportation department and the contact at the rental house come into play. The best boy's diplomacy is key.

Electricians

Q: How many electricians does it take to screw in a lightbulb?
A: It's not a bulb, it's a *globe*.

Electricians are affectionately known as *juicers* or *sparks* and are officially titled *set lighting technicians* or *lamp operators*. The electrician's primary responsibility is placing and focusing lights according to the wishes of the gaffer. At each location, the electricians unload and reload the lighting equipment from the trucks, run cabling, and run the distribution of electrical power for the lights. On the set, electricians are responsible for placing and focusing (aiming) the lights; manipulating the intensity, direction, color, and quality of light; wiring practical lamps (such as table lamps and wall sconces), switches, and wall outlets on constructed sets; and anticipating the needs of the gaffer so that equipment is at hand when needed. Electricians usually take responsibility for securing lights and stands for safe use; however, the grip department also plays a role, such as hanging pipe or truss for the lights, securing a stand with straps, or screwing it down with grip-chain.

There is a Zen to the job of the lamp operator. An experienced lamp operator handles the equipment with deft speed and economy of movement that comes with familiarity. Through the exchange of a few words or hand signals, or by clairvoyance, the electrician grasps the gaffer's intention and manipulates the lamp to create the desired effect. His or her focused concentration is on two things: the activities of the lighting crew and the behavior of the light. The lamp operator is constantly attentive to the DP and gaffer and to fellow electricians who might need a hand. Simultaneously, the electrician is aware of the light falling, blasting, leaking, and spilling onto the faces and the surfaces around the set.

The set lighting crew may be asked also to provide power for fellow crew: camera, sound, dolly, and video village. Electricians typically relinquish responsibility for powering vehicles at the base camp to the transportation department. Although powering the base camp is technically within the union jurisdiction of lighting technicians (who are trained to handle electrical distribution), most of the time the gaffer simply does not have the personnel to spare for anything extraneous to the set. Movie electricians are very rarely licensed journeymen or master electricians. They are not qualified to wire buildings or work on power lines. Their job is lighting movies.

Rigging crew

A rigging crew is an important part of almost any project, be it a feature, episodic TV series, or even a television commercial. The rigging crew works ahead of the main unit, installing cable and distribution, hanging lights, and taking care of any work that will be time-consuming for the main unit to accomplish on the day of filming. This may involve weeks of work to rig a major set, or half a day laying in some cable on location. A rigging crew consists of a rigging gaffer, rigging best boy, and rigging electricians. A rigging crew is invaluable to a production, especially to the DP and gaffer. The thought, planning, and careful, unrushed work, testing, and troubleshooting put in ahead of time translates into smooth sailing for the shooting crew. A properly rigged set means that the lighting will look better, the onset electricians can work with greater efficiency, and the director will be left with more time to get the day's shots. The rigging crew usually also wraps out the set after the first-unit crew has finished with it. The electric rigging crew works in tandem with the grip rigging crew.

The fixtures guy

On a production for which a lot of practical fixtures and outlets are to be wired, it is valuable to have a fixtures guy (or gal). The fixtures guy is responsible for wiring any practical lights (typically wall sconces and chandeliers) and outlets in the set. The fixtures guy may also be employed to build and wire special fixtures for the gaffer (such as lights on a futuristic space vehicle). A good fixtures guy knows a great deal about dealing with practicals and creating practical lighting effects for production. One fixtures guy I know has bookshelves full of lightbulb and fixtures catalogs and is an excellent resource for the gaffer when a little research is required for a specific problem.

Generator operator

The generator operator is in charge of the full-time operation and maintenance of the generator. A knowledgeable, experienced generator operator is an extremely valuable person to the set lighting

department. This job was traditionally performed by a member of Local 40 (International Brotherhood of Electrical Workers, IBEW), who are trained electricians. However, most genny operators today are teamsters with special 40 cards. The production van driver typically operates the generators on the tractor. To get a 40 card to operate a generator, all a teamster has to do is pay dues to IBEW. There is no training, test, or apprenticeship program. As a result, you will find generator operators who have no special knowledge or training about generators. These individuals are of absolutely no use to you when a generator starts to hiccup. Especially when you are on a remote location where a generator cannot be quickly replaced and you encounter issues with climate, fuel, and other conditions that affect the generators, it is especially worthwhile for the gaffer and DP to insist on using a qualified generator operator.

Grip department

Q: How many grips does it take to screw in a lightbulb?
A: Grips don't change lightbulbs. That's electric.

Nonelectrical lighting equipment is handled by our brothers and sisters in the grip department. A grip is affectionately called a *hammer*. Silks, diffusion frames, flags, reflector boards, rigging, dollies and dolly track, cranes, jib arms are all in the domain of gripology. Lights, dimmers, and generally things with plugs are the domain of the juicers. You could say that the electricians do the lighting and the grips do the shading. Each time an electrician sets up a light, a grip is right next to him or her with a *grip package*, which includes a C-stand and whatever flags, nets, or diffusion frames may be needed in front of the light. Electricians graduating from the nonunion world may be used to grips taking charge of placing sandbags on the light stands, providing ladders, and leveling large stands when they are placed on uneven ground. On union jobs in Los Angeles, the electricians generally handle their own ladders, sandbags, and rigging hardware, such as pipe clamps. Grips handle gel and diffusion when used on a frame or applied to windows. An electrician applies the gel and diffusion when it goes directly on a light.

Grips are responsible for the safety of the rigging, and they are often called on to rig support for lighting equipment and backdrops. Truss, I-beam rails, chain motors, speed-rail grids, wall spreaders, and similar rigs are built by the grips. When lights are to be hung from an overhead grid or rigged to the wall of the set, the grips generally rig the support. An electrician then clamps on the light, plugs it in, and focuses it. When lights are mounted on a high platform, on top of parallels, in the basket of an aerial lift (Condor, Snorkelift, etc.), or on an elevated platform, the grips rig and secure the light and light stand. When an interior night scene needs to be shot during daylight hours at a practical location, the grips build big black tents around the windows to create darkness outside, while providing space for lights outside the building. During production the grips are in charge of removing, and reinstalling set walls as needed during filming.

The head of the grip department is the *key grip*. The key grip supervises the grips in the same way that the gaffer supervises the electricians. He or she works for the DP in tandem with the gaffer, supervising the grips in the placement of grip gear in front of each light.

The key grip's chief assistant is the *best boy grip*. The best boy grip coordinates the grip crew in the same way that the best boy electric does the electric crew.

The *dolly grip* is in charge of operating moving-camera platforms, such as dollies and cranes: laying and leveling the dolly track, moving the camera smoothly up and down and to and from exact

marks with precise timing. Grips also rig support for the camera when it is placed in unusual places, such as on top of a ladder or on the hood of a car.

THE COMPANY

> ***Q:*** How many executive producers does it take to screw in a lightbulb?
> ***A:*** Executive producers don't screw in lightbulbs. They screw in hot tubs.

A film crew is composed of freelance artists, technicians, and administrators who are brought together by the production company when the production is ready to be mounted. The producer and director select the department heads: the DP, production designer, sound mixer, editor, and so on. Each department head usually brings his or her own staff to the production. The DP recommends a gaffer, key grip, camera operator, and camera assistants with whom he or she prefers to work. The gaffer, in turn, recommends electricians he or she knows and trusts.

Each production brings new faces, new locations, and new circumstances, yet you can count on certain constants in relationships between electricians and the other departments.

Production staff

> ***Q:*** How many production managers does it take to change a lightbulb?
> ***A:*** None! If you'd just make it a day exterior we wouldn't have to keep screwing around with all these lightbulbs!

Officially, the crew is hired by the producer. Although the gaffer usually selects electricians for the crew, once an electrician is offered a job, it is the *unit production manager* (UPM) with whom he signs the crew deal memo. The UPM authorizes paychecks that are handled by the accounting department and issued through a payroll company.

The duties of the UPM include establishing and controlling the budget, making deals for locations and services, booking the crew, overseeing daily production decisions such as authorizing overtime and making schedule changes due to weather, and managing all the off-set logistics, including housing, meals, transportation, permits, security, and insurance. Because the UPM is responsible for the executing the budget, he or she must approve all equipment orders and personnel requests.

Some productions have a *production supervisor* as well as (or in some cases instead of) a production manager. This distinction between production manager and production supervisor is that a UPM has served many years as an AD and has joined the Director's Guild of America (DGA), whereas a production supervisor has not. Typically, a supervisor has previously worked as a production coordinator working in the production office, not on set.

The *production coordinator* assists the production manager. His or her duties include booking the crew, booking and returning equipment, ordering expendables and supplies, monitoring petty cash, distributing production information to the various departments, and coordinating and distributing the shooting schedule and script revisions. The production manager, the production coordinator, and their staff work out of the production office, along with the accounting department.

The director's team

The "director's team" consists of the ADs, the production assistants (PAs), and the script supervisor.

Assistant director

During preproduction, the first assistant director (1st AD) prepares the script breakdown and production schedule and coordinates the actions of every department and the cast. He or she plans each day's schedule, and gives final approval to each day's call sheet (which is usually prepared by a second AD). During production, the 1st AD runs the set. He or she is responsible for keeping the production moving and on schedule on an hour-to-hour basis. The 1st AD keeps everyone informed about the shots, constantly plans ahead and facilitates, coordinates, and motivates the actions of the crew in order to solve problems before they occur. The 1st AD must stay informed of any potential delays or problems. Every production company is required to have an appointed safety officer. On a studio lot, the safety officer is provided by the studio; for independent shows, the 1st AD is the default safety officer. Part of the 1st AD's job is calling and running safety meetings. An onset safety briefing—for which the all relevant crew are assembled—is given to alert the crew to the specific safety issues of the shot, the location, or the day in general.

The 1st AD is backed up by a 2nd AD, who in turn are helped by 2nd 2nd ADs and a squad of PAs. The AD staff takes care of the actors: coordinating their schedules, and ushering them through makeup, hair, and wardrobe and to and from the set. The AD staff also directs the action of background players (extras), and supervises crowd control.

ADs and PAs can be called upon to help coordinate between departments. For example, if an electrician needed some furniture moved to place a light and the onset dresser was nowhere in sight, the 1st AD would have him found in short order. Prior to the first take, the AD calls "last looks," which alerts the makeup, hair, and wardrobe onset personnel to make final touches. The 1st AD initiates each take by calling "Picture is up," a warning to everyone to finish whatever they are doing and get ready for the take. This is followed by "Roll sound." These instructions are broadcast over the walkie to all the ADs and PAs, who echo "Rolling" throughout the set, so that everyone knows to settle in for the take, and be quiet. Following the take, "Cut" is broadcast by the 1st AD, and again, the AD staff echo it for the crew.

The AD makes other announcements, such as:

"Going again." A second take will be rolling immediately.

"Hold the roll." There has been a momentary delay. This cues the sound mixer to stop recording while the problem is fixed.

"Check the gate." After the shot has been successfully completed and the director is ready to move on, the camera gate must be inspected before the next shot is announced. If there is a "hair" in the gate, the shot may have to be retaken. "Check the gate" is usually followed moments later by: "Moving on," "New deal," "Turning around," "Company move," or "That's lunch, one half-hour."

"Abby Singer is up." The Abby Singer is the second to last shot of the day. It was named for (former) AD Abby Singer, who always had "just one more shot" after the last shot of the day.

"Martini is up." The martini is the last shot of the day. (Your next shot will be out of a glass.)

"That's a wrap." This announcement is made after the last shot of the day has been successfully completed. If filming has been completed at this location, electricians then begin wrapping: taking down the lights, coiling the cable, and loading the truck. When filming will resume in the same place on the following day, and things can pretty much stay where they are, the ADs may say "Make it safe" or "Walk away."

"MOS." This phrase means that sound will not be recorded for the shot. The term comes from the early days of sound. It is an acronym for "minus optical stripe."

"Fire in the hole!" This is announced before a shot in which there will be gunfire or explosions. Be prepared for a loud noise to follow.

Script supervisor

The *script supervisor* makes careful notes on the script, and keeps a running log that shows scene and take numbers, lenses used, shot scale, movement, eyeline direction, good takes, flawed takes (and the reason why they were flawed), line changes including ad libs and flubs, and so forth. These notes are used to recall matters of continuity, and to note for the editor what coverage was taken, and which takes the director thought were the best. In a way, the script supervisor is the onset advocate for the editor, consulting with the director on questions of screen direction and coverage. Matters of continuity are often small details that have to be carefully noted—in which hand an actor holds his beer, at what point in the scene he puts out his cigarette, whether his shirt sleeves are rolled up . . . all the things that everyone sees but no one notices. For this reason, it is vital for her (or him) to be able to see the action on every take; if you stand in her way, you risk being jabbed by her sharp little pencil. The gaffer sometimes has the best boy take detailed notes on the placement of the lights, especially if the scene may be replicated at another time. The script supervisor can provide the best boy with the applicable scene numbers for these notes. The camera assistants and sound recordist also get this information from the script supervisor.

Camera department

Q: How many ACs does it take to screw in a lightbulb?
A: Five. One to screw it in and four to tell you how they did it on the last show.

The camera department is made up of the DP, camera operator, first camera assistant, second camera assistant, and a loader. When shooting in high definition (HD), the camera crew may include a *digital image technician* (known as a DIT) and a camera utility person in place of the loader. The *camera operator* sets the shot and operates the camera. The operator is charged with the responsibility of keeping the lights, grip equipment, and microphones out of the shot. If you are setting a light close to the frame line, the camera operator can tell you where it is safe. It is a very good idea that the camera operator set the shot before the lighting crew starts lighting it, as important details—such as the exact placement of the actors, and what background that will be photographed—may change during this process. Although this may cause the lighting crew to hold off on the work inside the set for a couple of minutes, ultimately it saves having to set lights twice.

The *first camera assistant* (1st AC) is responsible for the camera, including building it, configuring it for each shot, making lens changes, threading the film, running tests, and performing regular maintenance as needed. During the take, the 1st AC keeps the camera in focus and may perform any of a multitude of other tasks—zooming, making an aperture change, or ramping the shutter speed or angle. The 1st AC never leaves the camera's side.

From time to time, the 1st AC calls on the lighting crew to help get rid of lens flare—light hitting the lens that may flare on the image. Usually the grips can set a flag or hang a “teaser” to keep the light off the lens.

The 2nd AC and the loader aid the 1st AC with lens changes and magazine changes, mark the actors’ positions, slate each shot, and keep the camera reports and film inventory. Almost all camera equipment runs on batteries, but a 2nd AC needs power to run a video monitor. When a director uses a video monitor, it quickly becomes habit to supply power to the monitor as soon as the camera is placed. Similarly, a hot extension cord should be supplied for the dolly at all times.

Sound department

The *sound mixer* oversees the recording of audio and monitors the sound levels, and is generally responsible for the quality of the sound recording. The sound mixer is the one person on the set fortunate enough to perform his or her job from a sitting position. If you want to know the sports scores, he or she almost always has the newspaper at the sound cart.

The *boom operator* is the person who actually positions the microphone within range of the actors, by holding it on a pole over their heads, wiring them with radio mikes, or planting hidden microphones on the set. When a power cable must cross the microphone cable, the electrician should run it under the microphone cable so that it doesn’t restrict the boom’s movement.

The boom operator has to contend with shadows cast onto the actors and walls by the microphone and the boom pole. Boom operators are very good at analyzing the lighting and use great ingenuity to avoid casting shadows. The lighting crew helps the boom operator by setting toppers on lights as needed to eliminate microphone shadows. Certain lighting directions are inherently problematic for the boom operator. For example, hard front-light from the direction of the camera, tends to throw mike shadows onto actors, set dressings, or walls that are right in line with the actor being filmed. Raising the light higher so that the light is angled downward and then topping the light can eliminate the problem. Steep, top-down lighting is another difficult angle for the boom mike, because it tends to throw microphone shadows across the actor’s clothes or table surfaces. Sometimes, the lighting is such that a boom microphone simply cannot be used, and the sound department must accommodate by using other methods such as radio mics.

The sound department has a vested interest in the good placement of the generator. Even with baffles to deaden it, engine noise can be a nuisance. Ballasts and dimmers usually hum and can become a concern for sound. Place them as far from the microphones as possible—preferably in another room or outside. Obviously, cell phones must be *off* during rehearsals and filming.

Dimming, light cues, and lighting effects create electrical “noise” in the power supply. The sound cart should be powered via separate utility power. All crew members must check with an electrician before plugging in their own electrical equipment; mistakenly plugging an expensive monitor into a dimmer channel, for example, is an experiment you don’t want to be a part of.

Locations

Q: How many fire safety officers does it take to screw in a lightbulb?
A: One, but it’s an eight-hour minimum.

A script might call for a city street, department store, hospital, church, factory, private residence, prison, airport terminal, office building, hotel lobby, or postapocalyptic tundra. Many settings

can be more easily (and cheaply) filmed at an existing real site than recreated on the studio stage or lot. Whatever the case, the locations department finds, secures, and coordinates the film's locations.

When on location, any questions or problems pertaining to the building or grounds (such as rigging lights to the structure or access to locked rooms or circuit breaker panels) are handled by the building rep or building engineer through the locations manager or his or her assistants. The locations manager must sometimes wrangle tough situations with members of the public or employees of the location. It is best to defer any questions from these people directly to the locations manager or the ADs. The locations manager obtains permission to place lights in unorthodox places. Any kind of rigging that might do harm to a location or otherwise alarm the owner must be preapproved through the locations manager. Care must be taken not to damage the location. The places that are most at risk of damage are floors, walls, doorway moldings, and garden plants. When a house has hardwood floors, for example, the grips and electricians can put rubber crutch tips on the legs of the stands and ask that layout board be put on the floors to protect them. Some locations impose restrictions on the use of their property. Working on a period movie, you may well find yourself shooting in a historical building with irreplaceable architectural detail. It is often the locations manager's task to enforce whatever rules have been established at the location (and contractually agreed to by the producer)—rules that may conflict with the needs of the lighting department. In these situations, keep in mind that it is the director's desire to film the location and it is your job to make it work. It will usually involve extra time and trouble, but it is more important to keep the locations manger as an ally and to help preserve good relations with every location the company uses. In the greater scheme of things, it is better for our whole industry if the public views film production as a positive experience.

Transportation

Q: How many teamsters does it take to screw in a lightbulb?
A: Four. You got a problem with that?

The drivers are responsible for operating and maintaining all the production vehicles. In addition to the "production van" (usually a 40-foot truck that carries all the lighting equipment), transportation provides passenger vans to shuttle the cast and crew, stake-bed trucks with hydraulic lift gates for delivering equipment, and any other vehicles that are needed. Stake beds are particularly useful on location when equipment needs to be shuttled to several sites in one day or must be dispersed over a large area. Drivers may also be dispatched to make runs, and return or pick up equipment from suppliers. It is a good idea for the best boy to give the transportation coordinator as much advance warning as possible, as needs arise.

Art department

Q: How many art directors does it take to screw in a lightbulb?
A: Does it have to be a lightbulb? I've got a really nice candelabra we could use.

Construction builds the sets, *set dressing* decorates the set with items not handled by an actor, and the *props department* is responsible for anything that is handled by an actor. Wall lamps, practicals,

“oil” lanterns, and the like are provided and placed by the set decorators. Wiring them is taken care of by an electrician. During production, the *onset dresser* and his helpers are responsible for caring for the furniture and all elements of decoration. If a piece of furniture needs to be moved, or a picture frame removed from the wall, ask the onset dresser to do it. If you do it yourself, it will break; it’s an immutable Law of Set Dressing. Anyone who thinks that set dressing is nothing more than moving furniture is missing something. The onset dresser is in touch with unseen forces that hold objects together, until they are touched by an electrician, at which time the spell is broken and the object shatters into small pieces.

Hair, makeup, wardrobe, stunts, special effects, first aid, craft service, and catering are the remaining departments on the set that electricians need to consult from time to time. They are all essential parts of the production and it pays to stay on good terms with every department.

The general public

One more group with whom you will come into contact, especially when working on location, is the general public. Everyone on a film crew knows how important it is to establish and maintain good relations with the public. No one knows this more than the locations manager. On location, more often than not, a film crew is a guest in someone else’s house. We constantly hold up traffic and ask people to be quiet during takes. By our very presence, we often put someone out. Although typically the location is being paid well for the trouble, every flower that gets trampled in the garden, every unthinking curse word uttered within earshot of sensitive ears, and every piece of equipment left in someone’s way makes the public less inclined to cooperate and to let us do our work. A disgruntled neighbor may confront the first person he or she sees, sometimes quite rudely. It is the job of the locations manager and production manager to deal with complaints. As lighting technicians, our role in all this is minimal but important. Treat any comment or question from the public with politeness and professionalism. Help the locations manager stop trouble before it starts by pointing any complaints or problems his or her way. Get approval before placing a light somewhere that it is going to annoy civilians; that way, the locations manager has a fighting chance at preemptive diplomacy. When locations or production make specific rules or requests with regard to working in a location, know that they are doing so because the issue is *already* sensitive. If they tell you to wrap out quietly, they are doing so because there have *already* been complaints about the noise. Many communities have ordinances that require quiet after 10:00 p.m. and no trucks and work before 7:00 a.m. In cities like Los Angeles, New York, and more recently Toronto and Vancouver, a large segment of the population has had a bad experience with film productions, which makes it very difficult for production to work on location. There are also those who have learned that they can extort money from a desperate production manager and make noise and get in the way until they are paid. As much as possible, these are behaviors we’d like to change.

Okay, let me just finish off the list:

Q: How many stunt men does it take to screw in a lightbulb?
A: Five. One to screw it in and four to tell him how bitchin’ he looked doing it.

Q: How many studio execs does it take to screw in a lightbulb?
A: No one knows. Lightbulbs last much longer than studio execs.

Q: How many actors does it take to screw in a lightbulb?
A: 100. One to screw it in and 99 to say they could have done it better.

Q: How many screenwriters does it take to change a lightbulb?
A: The light bulb is IN and it is staying IN!

Q: How many editors does it take to change a lightbulb?
A: If we change the lightbulb, we'll have to change everything.

Q: How many grips does it take to screw in a lightbulb?
A: Two. One to hold it and the other to hammer it in.

BLOCK, LIGHT, REHEARSE, TWEAK, SHOOT

Progress on the set is measured in *setups*. A feature film crew may shoot two or three pages of script a day. For a television single-camera show, the average is four to eight pages per day, typically 20-30 setups per day. The AD and DP work together to determine an efficient shooting order for the needed shots. Conventionally, wider master shots are photographed first, establishing the lighting for the scene. Closer coverage, which usually requires refinements to the master setup, follows. All the shots that look in one direction, requiring one lighting setup, can usually be shot before turning around. Once coverage from one direction is complete, the AD calls "Turning around," and the camera is moved around to shoot the other way. The crew then relights the scene for the new camera angle. Once a scene is completed, the AD calls, "New deal," the company clears out the set, and the director and actors block out the next scene on the schedule.

Although it is convenient when the shooting order is efficient for lighting, the AD may have other priorities. Shot order may be arranged to give precedence, for example, to a particularly difficult performance or a stunt that destroys part of the set, or to finish the work of an underage actor who can work only limited hours by law. Removing and reassembling walls of the set is often necessary to accommodate camera movement and lighting. Because this takes some time and is labor intensive, "wall order" is the kind of thing that the DP and AD want to take into account when planning the shot order.

The only sensible way to proceed in filming each new scene is to follow the following five steps in order:

1. Block
2. Light
3. Rehearse
4. Tweak
5. Shoot

First the director, the DP, and the actors block the entire scene (i.e., plan the staging). During blocking rehearsal, the set is usually cleared so that the actors and director can work without distraction. The director and principal actors are called the *first team*. Once the scene is ready to show, the AD

calls a “marking rehearsal,” and all key crew pile into the set and watch. The gaffer, key grip, and camera operators learn a great deal from the marking rehearsal, and they must pay close attention, as this is typically their last chance to observe exactly how the actors intend play the scene before they have to start lining up shots and begin lighting. The 2nd AC marks the actors’ positions with tape at their feet.

Once the scene has been blocked, the actors are sent to makeup and the DP begins setting the shots and then the lighting. Often, the lighting crew has already roughed in some of the lights during a prelight. Stand-ins, who act as models for the gaffer and DP while the lights are placed, replace the actors. The *stand-ins* are known as the *second team*. The camera crew sometimes rehearses complicated camera moves using the stand-ins to save the principal actors from technical rehearsals.

Once the lighting is in place, the AD calls the first team back to the set for final rehearsal. He or she calls, “Quiet please. Rehearsal’s up.” The actors run through the scene with the camera and sound crew to iron out any remaining problems. The AC gets final focus marks. The timing of light cues or the actions and camera movement may be adjusted. After one or two rehearsals, the scene is ready to shoot.

Block, light, rehearse, tweak, shoot is a paradigm that provides all the crew members the information they need to act independently to bring all the details of the shot together smoothly. Nonetheless, there are times when some directors and ADs would clearly prefer to bypass the first four steps. The truth is lighting without blocking first always causes delays when the actors arrive and do things differently. Actually seeing a blocking rehearsal of the action gives the crew almost all the answers they need to prepare the scene. Not doing so leads to a barrage of unanswered questions. Trying to shoot without rehearsing and tweaking almost always results in delays while problems are addressed, followed by retakes. The DP needs an opportunity to tweak the lighting after the final rehearsal because inevitably the actors will sometimes need to do things differently than they rehearsed, or differently than the stand-ins did it. During the final rehearsal, the DP will often see a problem that needs to be addressed before shooting. When time seems like a luxury the director cannot afford, it is far better and faster to block quickly, light quickly, rehearse quickly, tweak quickly and shoot, than it is to shoot now and ask questions after.

One final piece of set etiquette that every crewmember bears in mind: stay clear of the actors eyeline during rehearsals and takes. Be mindful of the level of concentration that acting requires, and cause as little distraction as possible.

THE WORK WORLD

To read more about the work world of television and motion pictures, you can find articles on the *Set Lighting Technician’s Handbook* Web site. These include information about the unions and union contracts, protections for workers, training, staying healthy in our line of work, job hunting, and networking.

CHAPTER

2 Preproduction planning: Lighting package, expendables, and personal tools

PREPRODUCTION PLANNING

During preproduction, the gaffer, rigging gaffer, and/or best boy meet with the DP and scout locations and sets, with the primary objective of compiling equipment lists and estimating manpower. Everything that will be needed to light the sets and locations needs to be set down on paper so that equipment vendors may prepare price quotes. The lighting order always represents a major expense to the production, so the UPM is eager to see the equipment list as early as possible in order to solidify deals with vendors and know where the budget stands. The UPM may come back the gaffer to negotiate if the lighting cost for a particular set is beyond what the production can spend. The gaffer and DP may have to consider other solutions to create the lighting that is required, but a knowledgeable gaffer can often justify expenses to the UPM by showing how his or her plan saves money or time during production. To come up with a complete equipment list, the gaffer needs pretty clear ideas about how each scene will be lit. The gaffer reads the script carefully, making notations and raising questions for the DP. He or she discusses scenes with the DP. The input of the director, production designer, and costume designer often steer important lighting decisions. When scouting the locations and looking at the sets, the DP, gaffer, key grip, and rigging keys (rigging gaffer and rigging key grip) are confronted with the particular challenges they'll need to address: how lighting effects will be created, how lights or lighting platforms shall be rigged, what control (dimmers or other) will be required, what gel colors will be used, and what special accessories are needed. These determinations translate into the specific lights and equipment needed, how much power, how much cable, and so on.

Each step of the way, the gaffer and rigging gaffer must consider three things: equipment, personnel, and time.

Equipment: What basic equipment will the lighting department carry for the duration of the show? Which scenes require additional equipment (e.g., a set with a big backing or green screen) or special equipment (condors, wet locations protection, specialty lighting equipment, and so on)? Will the transportation department need to furnish extra vehicles on particular days to move equipment from place to place?

Personnel: How many extra electricians are needed to operate this special equipment (condor, dimmer board, follow spot) or to prerig or wrap out cabling and equipment? Are certain days on the schedule particularly difficult, or will large locations require extra hands?

Time: What prerigging is required to achieve efficiency during shooting? How much time does it take to get into and wrap out of each set? What might cause lighting delays the DP and production department should take into account? What workable solutions can the gaffer suggest?

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Additionally, the gaffer and DP, in collaboration with the production designer, determine what special considerations should be given to the lighting in designing the sets. Designers are generally very conscious of lighting, and design the sets with windows in places that will make for good lighting; however, looking over the designer's plans allows the DP, gaffer, and key grip to consider practical matters such as access to the set, placement of wild walls (walls that can be removed), and removable ceiling pieces. These considerations will forestall impediments to the lighting.

The gaffer and DP discuss how they will approach the material: the mood and style of the film, the color palette, the working light levels, the kind of shots (Will a Steadicam shot reveal every corner of a room, requiring that all lights be hung above or outside the set?). Each of these questions affects the equipment the gaffer needs.

Scouting locations

The director, assistant director, and department heads scout each location in a group; the director and first AD present an overview of how the scenes are played out. This is the gaffer's opportunity to ask questions and coordinate crew members' actions. The DP and gaffer formulate a rough idea of how they will light each space. If the lighting is complex, notes from the scout will be drawn up as light plots. Notes are invaluable during future discussions. The gaffer, best boy, and rigging gaffer consider the special rigging required, special equipment required, location of the staging area, and placement of the production van. During the scout, they gather the information they will need to adapt the space for lighting. Aerial lifts or parallels may be employed outside the windows to support large lights. Wall spreaders or other lighting support may need to be rigged near the ceiling. Windows may need to be gelled or tinted.

In addition to absorbing this information, the best boy and rigging gaffer need to determine routes of access to each set for cabling. They must coordinate with the transportation and locations departments to ascertain where the generator can be placed to be as close to the set as possible without causing sound problems. They must learn from the DP, AD, and director how the feeder cables can be run to the set without entering into the shots. If house circuits may be used, the best boy locates and examines the breaker box to determine its capacity and the layout of circuits. He locates the light switches for sconces and house lights. He works with the locations manager and the contact at the location to gain access to locked rooms or arrange for lights to be placed on a neighboring property. He must find the service entrance through which to bring in carts and equipment without encountering stairs. He must locate the elevators. If large numbers of fluorescent lights are needed, he must get a count of the number of tubes to be ordered. In short, he must fully think through the lighting needs at each location.

Once the locations have been scouted, the gaffer and best boy look over the production schedule; evaluate personnel, equipment, and time requirements; and write up an equipment list, an expendable supply list, and a calendar showing when special equipment and additional labor will be needed.

Production meetings

At least one major production meeting is held before production begins. This is scheduled after all the tech scouts have been completed and is attended by all the department heads. The meeting is led by the first assistant director. Typically either the shooting script or the production schedule is used as an itinerary. The AD goes through the script scene by scene and describes all the major

elements of each scene. Questions and concerns from any department are raised and discussed. Issues that involve a great deal of interdepartmental cooperation are the most important to flush out in detail. Decisions involving only two parties can be identified and deferred to separate meetings. The gaffer and key grip are required to attend, listen, and contribute when it is helpful. This is usually a long and painful meeting, but it is often the only opportunity for everyone to learn about the plans and needs of other departments that might affect them.

EQUIPMENT PACKAGE

The size of the lighting package for a feature film or television show varies depending on the scale of the show. However, it may be helpful to introduce the basic elements contained within a typical lighting package. Each of these is covered in great detail in later chapters of this book, along with many more specialized lights.

Tungsten Package (Chapter 3)	
Small Fresnels	A clean focusable light (flood/spot) with a high degree of beam and brightness control
Open face	A broad light used as a bounce source or to light set elements
PARs	PAR cans (sealed-beam lamps) provide a powerful beam for bright highlights or long throw in a relatively small, simple, inexpensive fixture
Ellipsoidal spot	Highly focused controllable beam with a long throw and exceptionally even field with very clean edges (typically 750 W–1 kW)
Big lights	10–24 kW Fresnels, or large arrays of PAR lights (6 kW-36 kW) often used to create bright sunlight effects, or to light large areas
Area lights	Large soft illumination to evenly light an area from overhead, or to light a backdrop. These include coop lights (6 kW), space lights (2, 6, and 12 kW), large fluorescent fixtures, sky pans (5–10 kW) and cyclorama lights
HMI Package (Chapter 8)	
Fresnels	Daylight color-balanced clean focusable light (flood/spot) with a high degree of control, suitable for lighting actors (200 W–24 kW)
PARs	Daylight color-balanced light with a very powerful beam for bright highlights or long throw (200 W–18 kW)
Fluorescents and LEDs (Chapters 9 and 10)	
Portable	Small, lightweight, adaptable fixtures that make soft light. Often used to light actor's faces. May use either tungsten-balanced or daylight-balanced tubes
Backdrops	May include 8, 10, or more tubes per unit. Green-screen or blue-screen lights, or tungsten or daylight-balanced lights; easy to control on a console
Accessories (Chapters 4 and 13)	
Stands	There are many different kinds of light stands, from short to very tall, from lightweight to heavy steel. Checklist 2.3 enumerates the checkout procedure for stands
Clamps/rigging	Mounting hardware to hang a light practically anywhere
Chimeras	Attaches to the front of any light to provide diffusion without the need for lots of grip equipment to block the spill

Continued

Dimmers	Individual small 600–2000 W dimmers, handy for setting levels on lights and practicals and for varying light level by hand during a shot. Dimmer packs and large dimmer racks provide control from a lighting console of dozens of light channels (1.5-24 kW)
Specialty Lighting Equipment (Chapter 17)	
Car kits	Small battery-powered lights commonly used in moving vehicles
Tower lights	A truck with self-contained generator, tall boom arm 50-80 feet high, with large lights with remote pan tilt and focus capability used to light a large night exterior
Follow spot	Typically associated with a venue such as a concert
Xenon lights	Powerful very narrow shaft of daylight colored light, 1-7 kW
Lightning effects	Very bright flashes of light to create a lightning storm
Control Equipment (Chapter 11)	
Control console	Generates the DMX512 signal to communicate with dimmers and DMX512-controlled light fixtures and devices
DMX512 network	DMX512 cables, opto splitters and isolators, and associated gear
Distribution Equipment (Chapter 13)	
Feeder cable	Runs from power source to the vicinity of the set
Spider/junction	Branches the feeder to serve multiple distribution boxes
Distribution box	Provides outlets for the lights (240 V 100 A, 120 V 100 A, 60 A, and 20 A)
Extensions	100, 60, and 20 A to feed the lights
Wet locations	Ground Fault Circuit Interrupter (GFCI) protection. Special protection to prevent a potentially dangerous level of leakage current
Power Sources (Chapter 16)	
Battery packs	
Large power plant generators	
Small portable generators	
Transformers	

The load-in

The load-in is the first day of work for an electrician on a feature film. The best boy supervises the checkout and load-in, making sure the lighting order is correctly filled and all the equipment is in full working order. The checkout must be extremely thorough. Even at the best rental houses and studio lamp docks, you cannot assume that all the equipment is in perfect working order or leave the counting to someone else. At the completion of filming, any broken or missing items are charged to the production as "lost and damaged." There are a lot of ways to foul up the paperwork: orders are often changed at the last minute, and special equipment may come from more than one rental house. Almost always, a few items require maintenance or are miscounted by the rental house, so count and check the equipment carefully.

Lights

Each light should be tested at checkout. Once you establish a routine for checking lights, it takes very little time to check all the items listed in Checklists 2.1 and 2.2, but take the time; you do not want to discover problems on the set when production is in full swing.

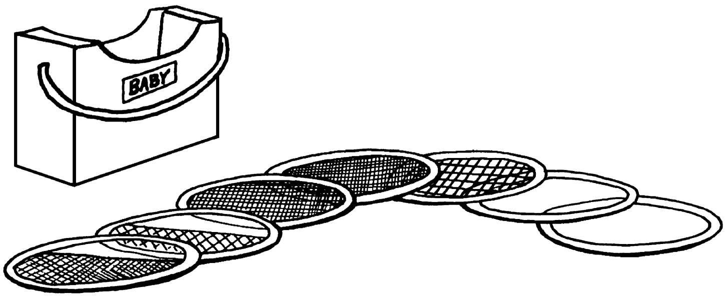

FIGURE 2.1

Complete scrim set with box. The Hollywood set includes (from left to right) a half double, half single, two doubles, a single, and a set of gel frames.

CHECKLIST 2.1: FRESNEL AND OPEN-FACE TUNGSTEN LAMPS CHECKOUT

- ◻ Check whether each light is complete. Each must have a full set of scrims, a scrim box or bag, and barn doors. Count the scrims. A complete five-piece set includes two doubles, one single, one half double, one half single, and one gel frame (Figure 2.1).
- ◻ Check the fit of barn doors. Check for floppy doors. Most gaffers prefer four-leaf to two-leaf doors. Doors should be fitted with safety chain.
- ◻ With the power disconnected, open the fixture and *check the condition of the reflector*. Especially with hot-burning lights such as baby-babies or baby-juniors, the reflector can become warped and discolored by prolonged use tilted steeply downward. The reflector must be properly aligned, unbent, clean, and in good condition.
- ◻ Inspect the bulb for blisters and bulges, evidence that the bulb has been mishandled and burnout is imminent.
- ◻ Check whether the lens is clean and free of cracks. A little dust buildup on the lens cuts the light output in half.
- ◻ Check whether the T-handle threads properly. The threads sometimes get stripped.
- ◻ Check whether the tilt lock knuckle holds the light firmly. The cork disks at the swivel point wear out and occasionally need to be replaced.
- ◻ Check plugs for signs of overheating—discoloration, malformation.
- ◻ Plug in each fixture and turn it on to check the bulb and the switch. Make sure that you have any needed connector adapters. Wiggle the cord at the switch and lamp housing to ferret out any intermittent discontinuity (problem with power cord or lamp base contacts).
- ◻ Check the flood spot mechanism for smooth, full travel. Observe the beam as it changes. An uneven or odd-shaped beam is evidence of an improperly aligned bulb or a bent or damaged reflector.

CHECKLIST 2.2: ADDITIONAL STEPS FOR HMI CHECKOUT

- ◻ Each unit should be complete with scrim set, barn doors, lens set (PARs only), two-head feeder cables, ballast, and power feeder cable.
- ◻ Hook up and turn on each light, using both head feeders. Inspect the head cables for bent pins or misthreaded connectors, cuts in insulation, and a loose strain relief collar at connector.
- ◻ Allow several minutes to reach full output. Using a three-color color temperature meter, measure the color temperature and green/magenta shift of each unit. Mark these measurements on a piece of white camera tape and tape it to the bail of the light. Also include the date and the unit number.

Continued

CHECKLIST 2.2: ADDITIONAL STEPS FOR HMI CHECKOUT—Cont'd

- ☐ Number each head, and globe box, so that the same head and globe are always used together. Or name them (for example, Curly, Larry, and Moe.)
- ☐ Watch for unstable arcs. You can use a welder's glass to observe the bulb through the lens.
- ☐ You may want to check for ground faults and leakage current from the head and the ballast, especially when working in damp conditions. Current leaking to the lamp housing or ballast casing give you a nasty shock if you become well grounded (as when standing in wet grass). You can run into this problem if there is a weak short in the cable, the head, or the ballast. Use a GFI device to test the lights (see Chapter 17). This special type of circuit protection trips if it detects leakage current.
- ☐ You may also want to test the restrike capability of the light by turning it off and attempting a restrike after 15 seconds. If the light will not restrike, try again once every 60 seconds to see how long you have to wait. Note: repeated unsuccessful ignition attempts discolor the inside of the bulb; don't overdo it.
- ☐ Inspect the bulb for blisters and bulges, evidence that burnout is imminent.
- ☐ Check that the lens is clean and uncracked. Dust on the lens cuts light output in half.

CHECKLIST 2.3: STANDS CHECKOUT

- ☐ Raise each stand to full extension. Check for binding and corrosion. Test the lock of each T-handle.
- ☐ Inspect for bent or broken braces and loose or missing brace bolts.
- ☐ Crank stands and motorized stands should be tested by raising and lowering the stand with a sandbag on the top. The weight is necessary to prevent the stand's inner mechanism from binding when lowered.
- ☐ Pneumatic tires should be fully inflated and roll smoothly.
- ☐ Check that the wheel swivel locks, brace hinges, collars, and so on operate properly.

The production van

When shooting on location, the lighting crew works out of its truck. Depending on the size of the production, the vehicle may be anything from a cube van, to a 10-ton truck or a fully customized, 40-foot, 18-wheel production van. A fully equipped production van like the one shown in Figure 2.2 is complete with dual generators mounted on the tractor. The truck comes equipped with shelving for the lights, brackets on the doors to hold stands, a large hydraulic lift gate, one or more side doors with stairs, interior lighting, and a well-organized design. Smaller 5- and 10-ton trucks have jockey boxes underneath both sides of the truck that carry cable and sandbags. Larger trucks have doors along the length of the belly that can hold a substantial quantity of cable and distribution equipment.

Head carts and cable dollies (Figure 2.3), milk crate carts for stinger crates, practical bulbs and wiring devices, dimmers, and so on (Figures 2.4 and 2.5) are all typically part of the equipment package.

EXPENDABLE SUPPLIES

Expendables are supplies that are purchased and used up in the course of production. In addition to equipment inventory and checkout, the best boy and electricians use prep days for organizing and prepping expendables, cutting gels for the lights, and completing any similar tasks to get everything ready for the first day of shooting.

FIGURE 2.2

A 40-foot production van with two tractor-mounted generators.

(Courtesy Mike Ambrose.)

FIGURE 2.3

The production van houses all the equipment for transport. Note that the head carts are loaded and strapped to the walls. Two cable carts are pictured at left. Further to the front of the truck shelving holds other lights, and supplies.

(Courtesy Mike Ambrose.)

FIGURE 2.4

The expendables cart carries milk crates which typically store practical lamps, spare lamps, hand dimmers, tape, sash, velcro, hardware, and so on.

(Courtesy Mike Ambrose.)

FIGURE 2.5

Gel rolls are stored on the back side of the expendables cart. Rolls of diffusion, ND, plus and minus green, CTO, CTB, and CTS gels are typically carried. The cart on the right holds Kino-Flo lights and parts.

(Courtesy Mike Ambrose.)

Gels and diffusion

Colored gels and diffusion material comes in 4-foot-wide rolls and in sheets. Cuts of gel are kept in a crate, sectioned according to size and color (Figure 2.6). This practice makes gel use fast and easy on the set and ultimately saves gel because less is wasted. Precut color correction gel and diffusion into squares of 6, 8, 10, and 12 in., and a couple cuts of 20 and 24 in. (A 6-in. square fits inside the barn doors of units 1k or smaller. An 8-in. square fits studio babies and baby juniors. The 10- and 12-in. sizes fit inside the doors of regular juniors and outside the doors of lamps 650 W and smaller. The larger cuts of gel fit on the outside of the doors of 2ks, 1200 HMIs, and PAR lights.) Anything larger than 24 in. can be gelled using a frame supplied by the grips.

The best way to cut gel from the roll is to use a template. Cut a 24-in. × 48-in. piece of ½-in. plywood and mark out a grid pattern of 6-, 8-, 10-, and 12-in. squares. Use a Skilsaw to score along the marks, making grooves ⅛-in. deep. The matte knife blade slices down the grooves and makes cutting gel very fast, neat, and easy. The smaller cuts can be made from the scraps left over from the larger cuts. Once the gel is cut and organized, the gel crate finds a home on the cart, where it will remain close at hand during shooting. Assorted rolls of gel may be kept on the head cart; the remaining rolls are stored in boxes on the truck.

Electrical expendables

A production may or may not require all of the items described here. During prep, these items are organized in the drawers of a work box, crates on the milk crate cart, and boxes on the shelves of the truck. Label each drawer, crate, and box with its contents. A large-capacity toolbox with drawers makes an excellent storage place for all the small expendable items (Figure 2.4).

FIGURE 2.6

Cut gel and diffusion are marked with permanent marker and stored according to size and type. Here, short sections of PVC pipe create a convenient gel organizer.

(Courtesy Mike Ambrose.)

Black wrap: Black wrap is a durable black foil used on hot lights to control spill and shape the beam. It is available in rolls of 12 in. (50 ft.), 24 in., and 36 in. (25 ft.). White wrap is also available.

Clothespins (nicknamed C-47s or bullets): These are used to attach gels and diffusion to the lights.

Binder clips: (the metal spring-loaded oversized paperclips) are also handy for attaching gels and fabricated snoots.

Rubber matting: Matting is used to cover power cables where they cross doorways and other traffic areas. It comes in rolls 24 in. wide, up to 100 ft. long.

Sash cord: Sash cord is made of white cotton rope. It is used for tying cable to pipe, among other things. Commonly used weights are #6, #8, and #10.

Trick line and mason line: These are #4-weight nonstretch rope. Trick line is black. Mason line is white. It comes in handy for odd jobs, such as making stinger tie strings and power cord hangers.

Bungee cords and S-hooks: Black rubber bungee cords come in various sizes and should be ordered to fit the shelves of the truck and carts.

Cube taps: Cube taps are used for plugging several low-amperage lights into one outlet. General Electric makes a cube-shaped tap from which the device gets its name, but any connector that serves the same function may be called a *cube tap* (15 A max). See Figure 2.7.

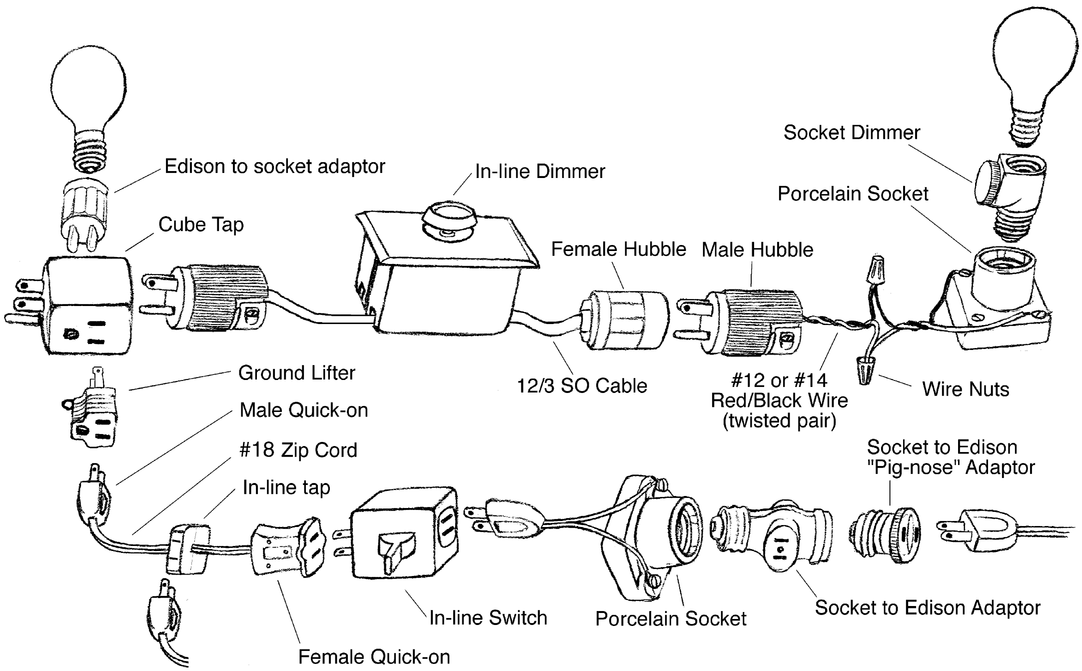

FIGURE 2.7

Electrical supplies.

Ground plug adapter: A ground plug adapter is used to adapt grounded plugs to the ungrounded outlets found in older buildings. It is also called a *cheater*, *ground lifter*, or *two-to-three adapter*. See Figure 2.7.

Quick-on plugs: These are small, low-amperage Edison sockets and plugs that can be connected to #18 zip cord quickly with no tools. Quick-on plugs can be used on small practical lamps. See Figure 2.7.

Zip cord: Light 18-gauge household lamp cord used for wiring small practical lights. See Figure 2.7. Part 530 of the National Electrical Code (NEC) requires that all cords and cables used for set lighting be hard usage or extra hard usage cables. Zip cord does not meet this requirement, so therefore quick-on plugs, add-a-taps, in-line taps and zip cord are not approved for lighting devices except where the cord is part of an approved assembly like the cord of a table lamp.

Wire nuts: A wire nut is an insulated cap used to splice two bare wires together. See Figure 2.7.

Dimmers: Household dimmers of 600 and 1000 W are commonly used to dim small lights and practicals. See Figure 2.7.

Porcelain sockets: Lamp sockets (medium screw base, E26) are used to mount lightbulbs in set pieces and soft boxes. Use porcelain sockets, because photo bulbs will melt plastic sockets. See Figure 2.7.

Socket dimmers: A socket dimmer (150 W max) screws in between the lamp socket and the light bulb, allowing the bulb to be dimmed. See Figure 2.7.

In-line switches: When rigging practical lights in sets, it is sometimes handy to have a plug-in 15-A switch on the line. See Figure 2.7.

Hubble Edison: The best boy stocks male and female Hubble Edison plugs to replace the plugs on stingers and power cords when they burn out. See Figure 2.7.

#12 copper wire: The best boy may want to have rolls of black, white, and green #12 wire, which is handy for wiring special lights and devices. A twisted pair of red/black wire is commonly used, too. See Figure 2.7.

Bus fuses: Spare bus fuses for deuce boards and bull switches are usually provided by the rental company.

Gang box fuses: These are 20-A BAF bus fuses, the essential replacement fuses for gang boxes. Gang box fuses blow routinely, so be sure to have plenty on hand.

Splitter fuses: These 60-A fuses are used in inline fuses on 100-A to two 60-A Bates splitters.

Electrical tape: Electrical tape is used for color-coding cables and spider boxes. It comes in a variety of colors (red, white, blue, black, and green) and is handy for insulating wire splices.

Gaffer's tape: Gaffer's tape is a heavy 2-in. fabric tape that rips cleanly in the direction of the weave. It is stronger, more durable, and more adhesive than paper tape.

Paper tape: Black 2-in. paper tape is handy for masking light. It has less of a tendency to pull the paint off walls than gaffer's tape.

White and colored cloth tape: This 1-in. and 2-in. cloth tape is used for labeling and color coding equipment.

Snot tape: (3M transfer tape) This is a sticky film that is handy for mounting gels in gel frames.

Best boy paint: Best boy paint is white, heat-resistant paint used to repaint the reflective surfaces of soft lights without altering the color of the light emitted.

Dulling spray: This is a spray applied to shiny surfaces to tone down reflective glints.

Streaks and tips: Colored hair spray is used to tone down or black out surfaces that are too bright. It is water-soluble, washes off easily after filming, and comes in shades of auburn, beige, black, blond, brown, gray, pink, silver, white, and others.
Practical bulbs: These are bulbs used in practical lamps, usually household (medium screw base) bulbs. Various types are used, among them photoflood bulbs, household bulbs, floodlights, spotlights, and small fluorescents.
Fluorescent bulbs: High color rendering index (CRI) tubes replace fluorescent tubes in offices and commercial buildings where the existing fluorescents are not correct for photography.
Flashlight bulbs: These are replacement bulbs for electricians' flashlights.
Batteries: use AA for flashlights; AAA for light meters; disk batteries for voltage/continuity meters; and 9 V for amp probe and light meters.
Cotter pins: Cotter pins are used when hanging lights to prevent the receptacle from slipping off the pin.
Visqueen heavy plastic sheet: A Visqueen heavy plastic sheet is used to protect equipment and electrical connections from rain, precipitation, dew, dust, and sand. It comes in 100-ft. rolls, 20 ft. wide (folded to 5 ft.).
Crutch tips: Crutch tips are put on the legs of stands to protect floors, in sizes of ¾ in. for small stands and 1 in. for large stands.
Refracil: Refracil is a heat-resistant cloth that will not burn when a hot light is placed on it. It protects ceiling and wall surfaces from heat damage.
Bailing wire: Bailing wire is a stiff wire, also called *stovepipe wire*.

Preparations may include the following:

Tape rolls: Put together a selection of tape rolls on a loop of sash cord: one roll each of 2-in. gaffer's tape, 2-in. black paper tape, and 1-in. white cloth tape. The electrical tape rolls (all colors) go together on a separate rope.
Practical bulbs: Mark and organize practical bulbs so their wattages and types are easily readable. Label the boxes. Insert foamcore dividers in a couple of milk crates. Stock compartments with various types and wattages to keep near the set. PH-bulbs (211, 212, and 213) do not have their rating printed on the top of the bulb. It is helpful to mark the top of these bulbs with a permanent marker: one dot for 211, two dots for 212, and three dots for 213.
Homemade boxes: Homemade lighting fixtures, such as soft boxes, are wired by an electrician. Soft box construction is discussed in Chapter 6.

TOOLS AND PERSONAL GEAR

Tool belt

When working on set, a lamp operator carries the needed tools and supplies on a tool belt (Figure 2.8) in a compartmentalized pouch. A flap folds over the tools to prevent them from falling out. Sharp tools (such as a knife) and delicate instruments (such as a voltmeter) are best stowed out of harm's way in their own protective leather pouches. Spread the weight around the belt to avoid putting stress on your back. Some electricians try to carry everything but the kitchen sink on their belts. They have tools hanging, clanking, and jangling from every part of their outfits. What you choose to carry varies depending on the circumstances. Keep additional tools in your personal kit or duffle.

FIGURE 2.8

Tool pouch.

Keep in mind that all the gear you buy for work is tax-deductible. Save your receipts. Every electrician should own the following tools (some of the following are illustrated in Figure 2.9).

Leather work gloves: Made of cowhide or some equivalent, these are used for handling hot lights or dirty cable and hardware. Clip them onto your belt when not wearing them. Leather gloves protect your hands from heat, abrasion, and grime. They cannot necessarily be counted on to protect you from electrical shock. Although they may provide electrical insulation when clean and dry, typically they are moist with sweat, making them a conductor.

Glove clip: A glove clip loops over a belt and provides a small spring clamp to hold gloves.

Screwdriver: Carry a flathead screwdriver and a Phillips screwdriver, or better, a single screwdriver with a reversible tip—flathead on one side, Phillips on the other.

Utility knife with retractable blade: Knives are used for cutting gels, foamcore, rope, and so on.

Scissors: Small, sharp scissors are often handy for making more careful cuts of gels and the like.

Wire snips: These are used primarily for cutting wire for practical lamps and making wire splices, but have other important uses (discussed later in this book).

Crescent wrench: An adjustable wrench is used to tighten a pipe clamp, adjust the friction of a bail, and perform countless other jobs. The standard 6-in. crescent wrench has a ½-in. maximum jaw opening that is too small to fit the ⅝-in. bolt used on many pipe hangers. You can find 6-in. crescent wrenches with an extra wide jaw, which are ideal, or carry an 8-in. wrench, which is bulky.

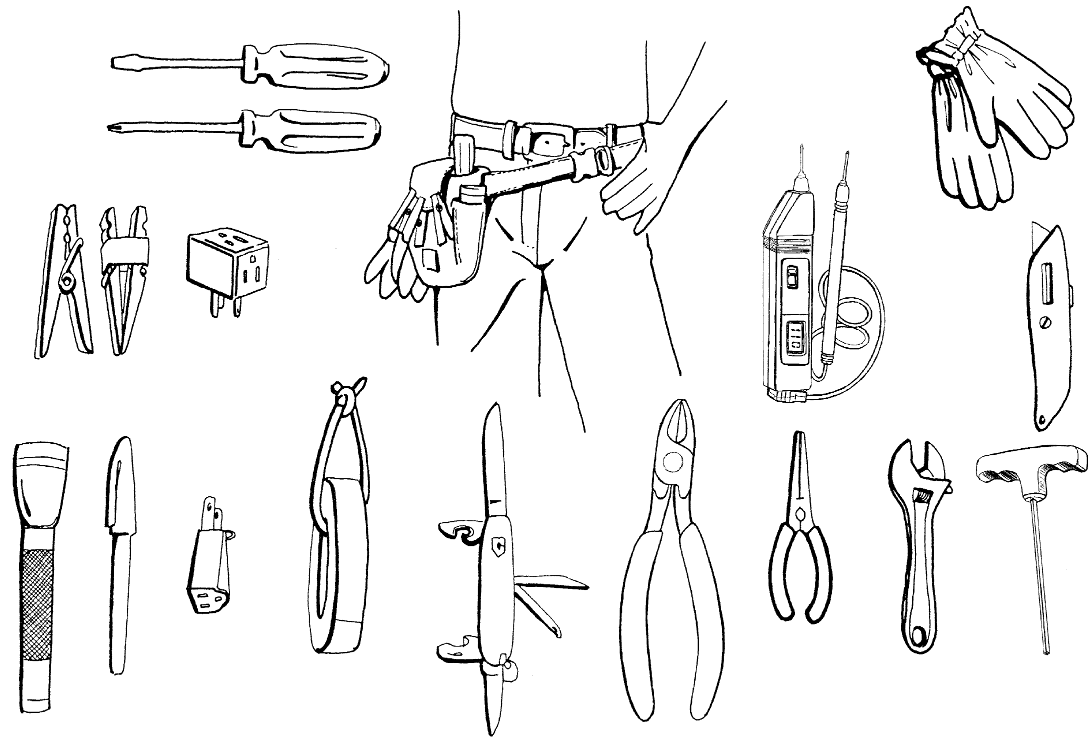

FIGURE 2.9

Tools and supplies.

Speed wrench: A ratcheted ⅜-in. square wrench is used for securing sister-lugs (square-headed setscrews) onto bus bars.

Needle-nose pliers: Needle-nose pliers are used for pulling hot scrims out of a light, small repairs, and so forth.

Bates cable tool: This tool performs three functions necessary for maintaining Bates connectors. It has a pin-cleaner, pin-straightener, and pin-splitter. It comes in its own pouch.

T-handle Allen wrench: When using lug cable, you'll need a 3/16-in. Allen wrench with a long insulated T-handle, which is used for tightening the setscrews on sister-lugs inside a spider box.

Voltmeter/continuity tester: A voltmeter/continuity tester is used to check line voltage (120, 208, or 240 V), check for voltage drop, and locate broken connections in power cords. A continuity tester tests for burnt-out bulbs and fuses and continuity in wires. Some models have a pushbutton on/off switch, which helps prevent inadvertently running down the batteries.

Circuit tester: Plugs into an Edison outlet and tells you whether the line is hot. Also indicates whether the polarity and grounding are correct.

Line sensor (voltage tick): This device indicates whether a wire has current flowing through it by sensing the magnetic field.

Flashlight: Electricians frequently find themselves working in the dark. When dealing with electricity, you always need to see what you are doing. Small, rugged, focusable flashlights are easy to carry on your belt.
Clothespins: Keep several on your belt. Figure 2.9 shows an inverted C-47 (a C-74), which is handy to pull hot scrims out of lights.
Permanent marker: This is used for labeling gels, fixtures, connectors, cables, and so forth.
Ballpoint pen: A pen is used for taking notes, filling out paperwork, taking down phone numbers, and so on.
Ground plug adapter: When on location, it is good to keep a couple cheaters in your pouch.
Cube taps: Keep a supply of two or three on you.
Gaffer's tape: Loop sash cord through the tape and attach it to your belt with a carabiner. If the roll is too bulky, you can make a "tape cube." Fold about 9 in. of tape onto itself, then continue to wind tape around until about 5 or 6 ft of it is wound onto the strip. The tape cube can go in your back pocket.

Meters

More sophisticated electrical measuring equipment may be useful to a best boy, generator operator, rigging gaffer, or dimmer board operator. These meters are used for troubleshooting and close monitoring of the power supply and electrical system. (Meters are covered in detail in Chapter 13.) Useful meters include an Amp Probe, Digital Multimeter, DMX512 tester, soco tester, and frequency meter.

Other hand tools

Some supplemental tools can make life easier. These are usually part of the gaffer's kit, kept in a workbox in the truck.

Automatic wire stripper: This tool provides a fast, precise way to strip insulation off the ends of wires. It is handy when wiring a lot of fixtures.
Rope wrench: This heavy-duty snip can cut cable or rope cleanly. It saves a lot of time and aggravation when making up stingers, wiring fixtures, or rigging with rope.
Crimper: These are used for crimping connectors onto wires, useful when wiring some types of fixtures.
Spider wrench: A special T-handle wrench for use on sister-lugs, the wrench fits over the outside of the sister-lug bolt. It can be very handy when an Allen slot gets stripped.
Electrician's scissors: These extra-tough scissors (they can cut through a penny) are especially useful for cutting metal gobo patterns, but also great for cutting gels, rope, and the like. (A gobo is a metal cutout used to make patterns in light).
Thumbscrew-type ⅝-in. wrench: A small, convenient alternative to carrying a big crescent wrench; does not provide as much leverage as a wrench but is great for ⅝-in. bolts on stirrup hangers.
Hand rasp (also called a rat-tail rasp): This rasp can pierce and saw through luan (the thin plywood used to make set walls). It is useful for cutting a quick rat hole in a set wall, to feed a power cord into the set.

Allen wrench sets or hex set (English and metric): These wrenches are used for fixing stands, among other things.
Full set of screwdrivers: The set should include a large and small Phillips, a very small flat-head screwdriver, a large flathead screwdriver, and a right-angle screwdriver for lamp head repairs.
Vice grips: These include small, needle-nose grips for clamping onto small parts while making repairs and large, crescent vice grips for getting a tight grip in a jammed pin connector.
Soldering iron and solder: For soldering electronics.
Cordless electric drill/screw gun: Especially useful when rigging, a screw gun is handy to affix devices to a wooden structure to keep them neat and organized.
Hammer: For hammering or pulling nails (more commonly a job for construction or grip dept.)
Steel tape measure: Dimensioning construction projects
Glue: Super-glue has a multitude of uses.
Large flashlights: It is handy to have some big flashlights when shooting at night. They can be passed out to electricians at the end of the night to perform a walk-around "idiot check."
Can handle: This is a handle that fits over the bull switch to provide comfort and leverage when throwing large, spring-loaded switches. If you throw a lot of switches, a handle can save you a lot of strain.

Personal gear

Electricians get dirty: jeans, a T-shirt, and work boots or sneakers are normal apparel. Weather permitting, it is advisable to protect your legs and arms with long pants and a shirt. Be prepared for the weather. In southern California, you might need only sunscreen, a baseball hat, sunglasses, and a jacket and jeans for after sunset, but be prepared for all weather conditions. You'll want to keep the following personal gear in your duffel bag:

- A full rain suit.
- Rain boots.
- Cold-weather jacket. Hat and gloves.
- A change of clothes in case you get wet.
- Consider the terrain. Hiking boots or work boots are often desirable.
- Sunscreen.
- Lip ointment.
- Mosquito repellent.
- Ear protection (disposable earplugs or head gear for when firearms are used).
- Eye protection (goggles or safety glasses). The special effects department usually supplies ear and eye protection to everyone who is needed near the action during explosions and stunts.
- Goggles and a bandana are needed when working in the desert. Blowing sand gets in your eyes, nose, and mouth and can practically blind you.
- *Map book*: In any metropolitan area, carry a map book with detailed illustrations of the streets. This will save you from getting lost and being late for work when the location map and directions aren't so good. You can't always count on your cell phone.

CHAPTER

3 Light fixtures: The basic tungsten arsenal

In this chapter, we'll discuss most common types of tungsten fixtures: Fresnels, soft lights, open face, parabolic aluminized reflectors (PARs), ellipsoidal spotlights (Lekos), beam projectors, area lights, cyclorama lights, and small specialty lights.[1] Each type of fixture has specific advantages for particular applications, determined primarily by its beam characteristics: brightness, focusability, evenness, punch, softness, size, shape, and color. The optical train of a light—the design of the lamp, reflector, and lens—determines the nature of the beam. This, combined with the special accessories each light employs, provides unique ways to manipulate and control the beam. We'll discuss different tricks to using each kind of light. In later chapters we'll see these optical methods applied to other kinds of light sources such as HMI and xenon.

THE TUNGSTEN LAMP

Before we begin our discussion of tungsten lights we first need to understand a little about incandescent lamps and color balance in photography. Film stocks and photographic sensors are designed to reproduce colors accurately when lit with light having a particular color makeup. The color makeup of a light source is quantified by its *color temperature*. Because tungsten filaments burn most efficiently at a color temperature of 3200 K (degrees Kelvin), *tungsten-balanced* film stock is designed to reproduce colors accurately when the subject is lit with tungsten (3200 K) light. Note that color temperature, expressed in degrees Kelvin, is a measure of the color output, not operating temperature.

Daylight-balanced films are designed to reproduce colors accurately when lit with light having a color temperature of 5600 K, or daylight. The graph of spectral power distribution (Figure 3.1) compares the distribution of energy across the spectrum of a tungsten source to that of daylight. Daylight is much stronger in the blue end of the spectrum, and tungsten light is much stronger in the red end. Color balance and color correction are explained in more detail in Chapter 6. In addition to naturally occurring daylight, metal halide arc lights, daylight-balanced fluorescent lamps, and LEDs also create something akin to daylight-balanced light.

[1]Tables listing specifications of most light fixtures are available on the Set Lighting Technician's Handbook Web site. The tables include details that may be of interest when planning a rig, such as weight, lamp type, lens size, scrim size, candlepower and beam angle (or range), and so on. Up-to-date information about a manufacturer's most current products is also easily accessed on the Web.

Set Lighting Technician's Handbook, 4e. DOI: 10.1016/B978-0-240-81075-1.00003-9

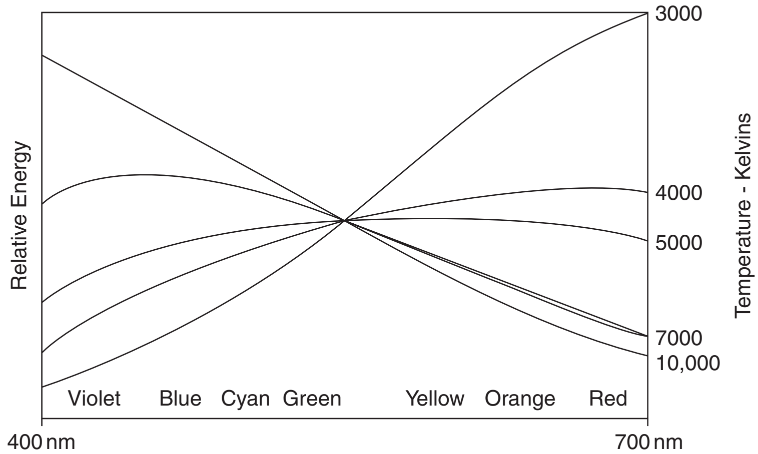

FIGURE 3.1

A spectral power distribution graph (SPD) illustrates the distribution of energy over the color spectrum. Incandescent lamps are strong in yellow-orange and red and weak in blue and violet. As color temperature increases, the curve shifts toward the blue spectral band.

In a *tungsten lamp*, light is created by running electrical current through a tungsten filament until it glows; that is, until it is heated to incandescence. The filament is held in an inert gas inside the sealed glass bulb to prevent the filament from simply being incinerated. Tungsten lamps can be powered by either AC or DC.

A *tungsten halogen lamp* is a type of incandescent lamp that contains special regenerative elements to prevent deposits of tungsten from blackening the sides of the globe. The regenerative elements carry the evaporated tungsten back to the filament, where it is reused, thereby increasing the life of the lamp. For the regenerative process, called the *halogen cycle*, to occur, a high temperature (at least 250 °C) must be maintained inside the globe; for this reason, tungsten halogen globes tend to be compact and made of quartz, which can withstand such a high temperature. In the old days, 10 kW lamps were the size of a melon and contained a cleaning agent that had to be manually swished around the inside of the globe between uses to clean off the tungsten blackening.

The standard type of globe used in each fixture is listed in Table B.3 (in Appendix B). There are often alternatives to the standard type: a bulb with a different wattage or color temperature, or one that uses frosted instead of clear glass. It is quite common to install alternative lamps, depending on the intended use. For example, a lamp with a color temperature of 3000 K often has a far longer lamp life than the same size lamp with a 3200- or 3400-K color temperature. You can use any lamp in a light fixture, as long as the lamp base matches the socket of the light fixture and the *lamp center length*, LCL, is the same. LCL defines the position of the center of the filament of the lamp, and centers it with respect to the reflector, the lens, and the rest of the optical elements. Lamp information available from GE, Sylvania, Osram, Phillips, Koto, Ushio, and others list specifications for every bulb and socket manufactured.

FRESNELS

The Fresnel (pronounced *freNEL)* is one of the most flexible fixtures to work with, being designed to create a relatively wide, even field of light with adjustable intensity and field size. The light from a Fresnel makes clean, hard shadows. Its clean beam makes it a good choice for lighting actors' faces, either directly or through diffusion. For these reasons, it is the most commonly used fixture in film and television (Figure 3.2). Figure 3.3 illustrates some Fresnel fixtures that every electrician should be able to identify.

The light is named for its Fresnel lens, which refracts the diverging rays of light emitted by the bulb into a controlled beam of light. The Fresnel lens has the same light-bending characteristics as a standard plano-convex lens, but the Fresnel's design compresses the convex curve into jagged steps (Figure 3.4), making it lighter and thinner, so that it retains less heat. The back of a Fresnel lens is frosted or slightly pebbled. This helps maintain a very even beam, and prevents the lens from actually projecting an image of the filament of the lamp.

Equally important, the fixture uses a *spherical* reflector. The reflector is really what gives the light its high level of control and even field characteristics, because the geometry of the reflector is such that light reflects straight back through the bulb (Figure 3.5). All light therefore emanates from a single point within the fixture (the filament), which is what allows the Fresnel lens to control the beam so cleanly. Some manufacturers utilize a polished reflector, which maximizes light output, and others use a slightly frosted reflector, which helps maintain a very even field of light.

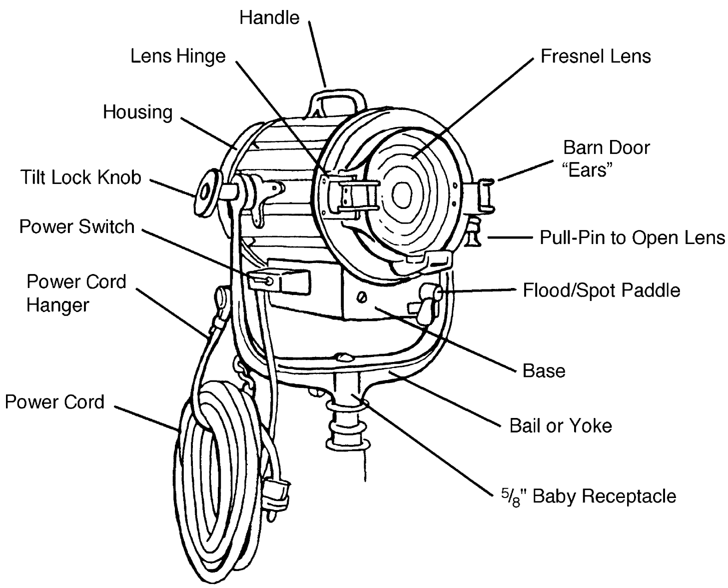

FIGURE 3.2

Anatomy of a Fresnel fixture.

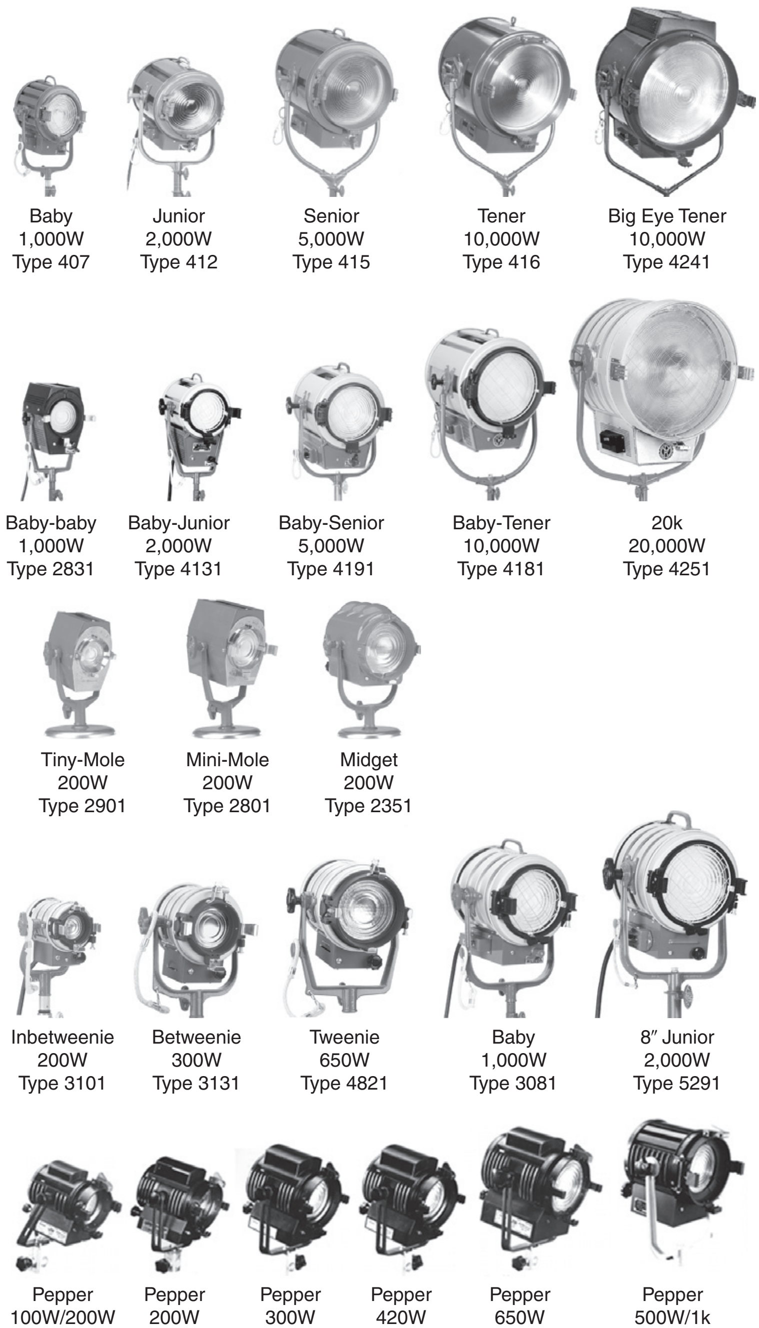

FIGURE 3.3

Fresnel fixtures come is all sizes from tiny 100 W fixtures to huge 20k fixtures. Note that our industry commonly refers to lights by there wattage as 1k, 2k, 5k, and so on. When we use the letter k, it really means kW. A 1k is a 1 kW or 1 kilowatt (1000 W) light.

(Courtesy Mole-Richardson Company and LTM Corporation.)

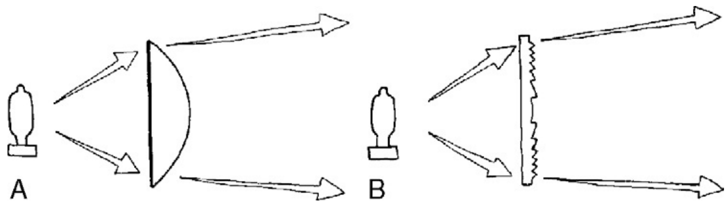

FIGURE 3.4

(A) A plano-convex lens pulls together the divergent rays of light. (B) A Fresnel lens has the same optical effect as the plano-convex lens, but it is cut away to reduce weight and heat retention.

Inside the housing, the globe and spherical reflector are mounted together and can be moved toward or away from the lens by an exterior adjustment knob. Moving the globe and reflector toward the lens *floods* the beam, increasing its spread and decreasing its intensity (Figure 3.5A bottom). Moving the globe and reflector away from the lens *spots* the beam, making it narrower and more intense (Figure 3.5A top). The adjustable focus makes it quick and easy to obtain the desired intensity or beam width.

Fresnel beam

To anticipate how the light will behave when an actor walks through it, it is helpful to have a three-dimensional mental picture of the beam's shape and intensity, the manner in which intensity falls off toward the edges, and how varying the amount of spot or flood changes these characteristics. Figure 3.6 illustrates the terms *field* and *beam*, terms used in describing the photometric[2] qualities of a fixture. A polar distribution graph (Figure 3.7) gives a clear picture of the "shape" of the beam intensity and how it changes from flood to spot.

At full flood, the beam is relatively even across a 40° sweep, then falls off quickly toward the edges. Fresnels end up used in flood position a lot. The flood/spot mechanism is often used for little more than to fine-tune the intensity. Note that in full flood, the beam has no central hot spot; the field is very even. As the lamp is spotted in, the rays become less divergent, more nearly parallel. The beam narrows and gets brighter in the center, falling off rapidly on either side. At full spot, the usable portion of the beam is narrow, about a 10° angle. The term *throw* refers to the distance from the light to the subject. A lamp in spot position has a greater throw; it illuminates the subject to the same brightness at a much greater distance. Table A.3 (Appendix A) gives the intensity at any distance for a variety of fixtures.

Photometrics, beam angle, and *field angle* are terms used in light manufacturers' sales literature; it is sometimes useful data to have during planning, but these are not terms you are likely to hear on set. In practice, electricians use these concepts all the time. For example, say that a large room is to

[2]Photometric data provided by a lighting manufacturer indicates the intensity of the light throughout its range of spot and flood. A typical Fresnel has a range from about 10° to 45° or 50°. Table A.2 gives the beam diameter at various distances for given beam angle.

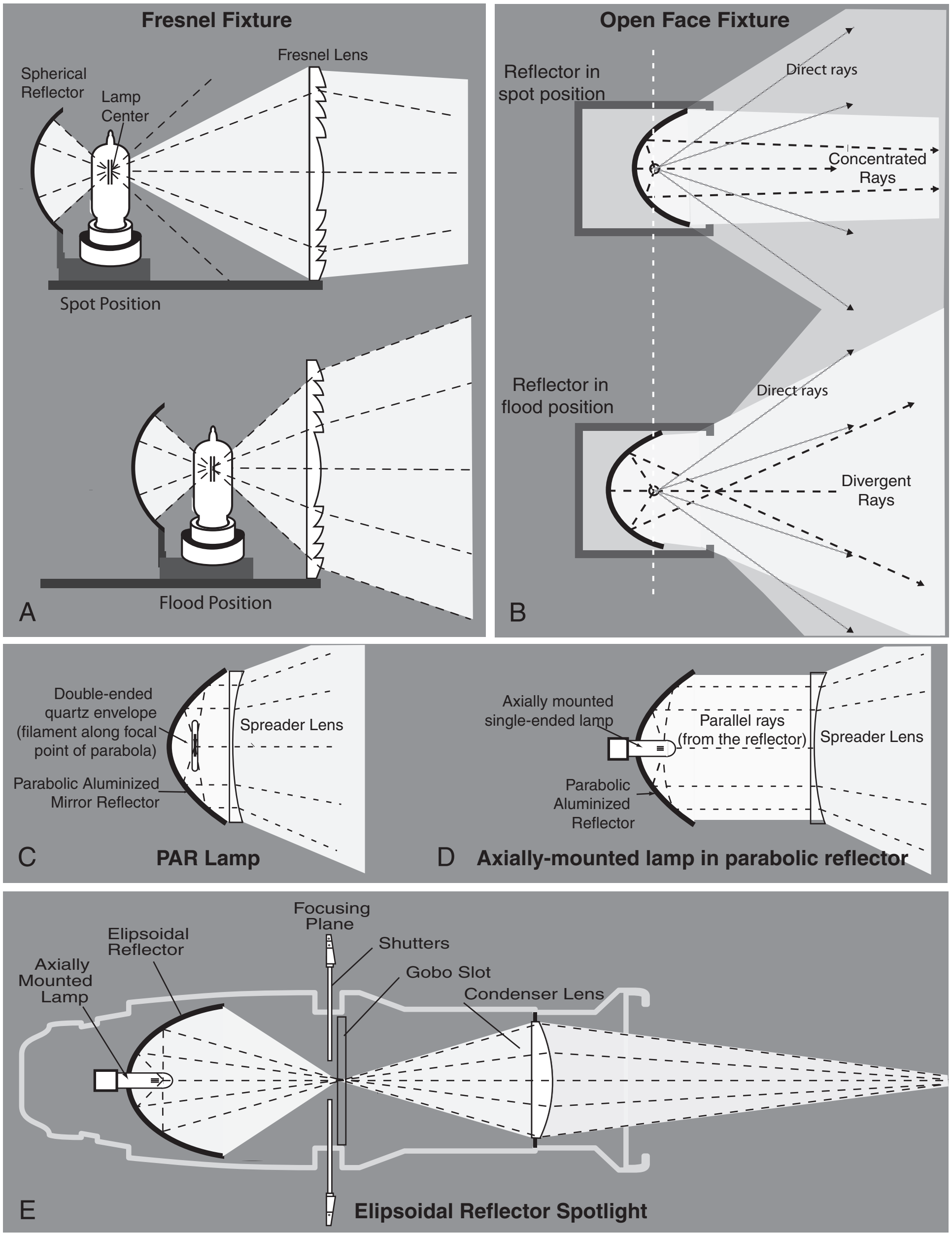

FIGURE 3.5

The design of the optical train—lamp, reflector, and lenses—affects the degree of control one has over the resulting beam as well as its efficiency and quality of the light. (A) Fresnel lights use a spherical reflector coupled with the Fresnel lens. (B) An open-face fixture comprises a simple lamp and reflector (which in this case has adjustable focus). (C) A parabolic reflector is used in PAR lamps and beam projectors to create a near-parallel shaft of light. (D) Many modern par fixtures employ an axially mounted lamp in a par reflector. (E) The ellipsoidal reflector on a spotlight requires focuses all the light gathered by the reflector. This allows the light to shape the beam with framing shutters and gobo patterns and project it onto a surface in sharp focus or de-focused.

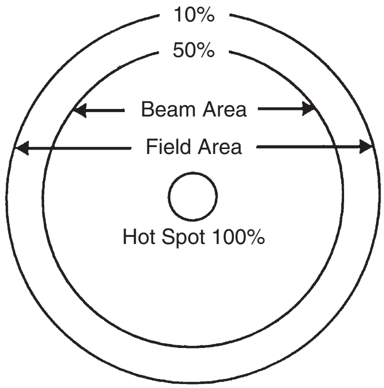

FIGURE 3.6

The field defines the “usable” light—the area of light that has an intensity of at least 10% of the peak value. *Beam* is defined as the “working light”, the area of light that has an intensity of at least 50% of the peak value. The *hot spot* is the brightest spot within the beam. The terms *beam angle* and *field angle* refer to the angle, from the fixture, of the beam and field, respectively.

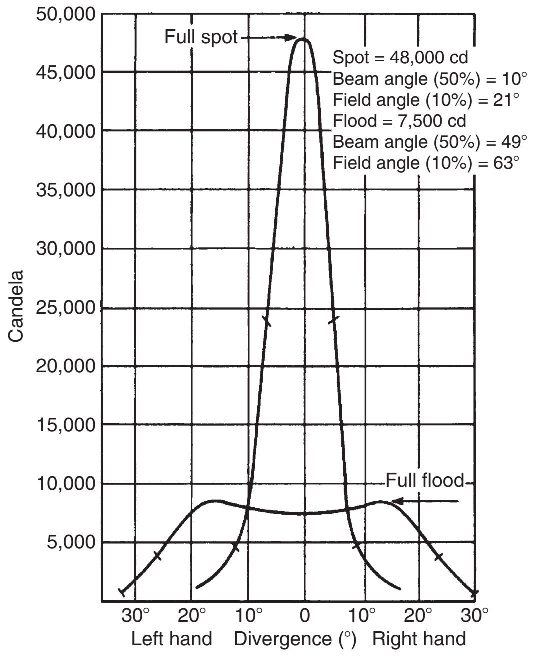

FIGURE 3.7

A polar distribution graph depicts light intensity across the diameter of the field of light. The upper tick marks denote the beam angle (the “working” light); the lower tick marks denote the field angle (the “usable” light). In the flood position, the light offers virtually even intensity across the wide spread of the beam; in the spot position, beam intensity falls off rapidly outward from the central hot spot.

be lit using several lights spaced evenly along one wall of the room. To make the light intensity even across the whole room, the lamps are set at full flood, and the edge of the beam of each light is feathered into that of the next. The beams overlap slightly at the 50% point, creating an even 100% intensity across the entire space. It is fairly easy to calculate the intensity and beam diameter of any light that has a focused beam (doing so for softlights is not so straightforward). A *candela* (cd) is a unit of luminous intensity (or candle power) equal to: cd = foot candles $\times$ (distance in feet)^2. Making photometric calculations is covered in detail in Appendix A.

A Fresnel creates its hardest, most delineated shadows at full flood. The more spotted-in the fixture, the *less* sharp the shadow lines appear. In full spot position, rays from the Fresnel travel more nearly parallel, but some converge slightly and cross one another. This creates a fuzziness to any shadow cast from an object. If one wants to project a sharp shadow or make a silhouette (e.g., the classic gag of a silhouette cast on a closed curtain), one would want to use a light at full flood.

Fresnel accessories

Fresnel lights should always be accompanied by barn doors and a set of scrims in a scrim box or scrim bag. A typical equipment package also includes snoots for each size of Fresnel light.

Scrims

A scrim is a stainless-steel wire screen used to reduce the intensity of the light. A single scrim has a loose wire weave, is identified by its green ring frame, and cuts the intensity of the light by approximately a half stop. A double scrim has a tighter weave, is identified by its red ring frame, and cuts the light by approximately one full stop. A standard Hollywood set of scrims includes a single, two doubles, a half-single, a half-double, and a gel frame. Quarter scrims and graduated scrims are also available for some fixtures.

Half scrims affect just one half of the beam. A "bottom-half double" can be used to even out the intensity of the light as the subject moves closer to the fixture (Figure 3.8). It reduces the light falling on objects close to the light, bringing the light level down to that of objects farther from the light.

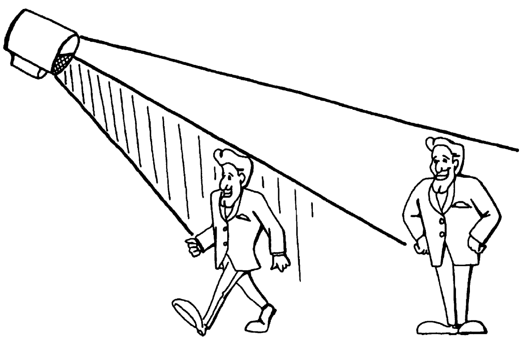

FIGURE 3.8

A bottom-half scrim is used to even out intensity as the subject moves closer to the light fixture.

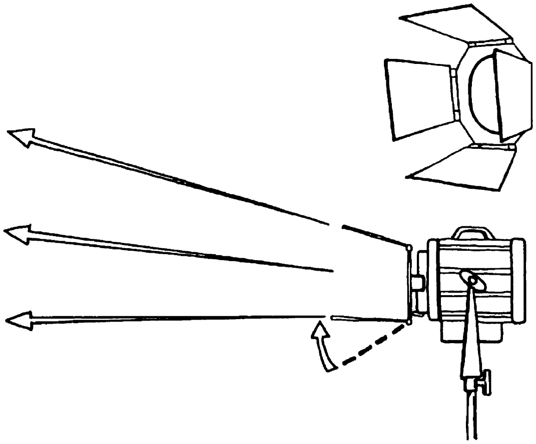

FIGURE 3.9

Barn doors contain the light, putting a straight edge on the beam.

A gel frame can be used to hold gels or diffusion for short spans of time; however, because of the heat close to the lens, many lights melt gels mounted in the gel frame. Similarly, hot scrims melt the gel in a gel frame (and make a big gooey mess on the scrim). Therefore, gels and diffusion materials are often attached to the barn doors, spaced apart from the hot scrims.

Barn doors

Barn doors provide the most basic control over the placement of the edges of the beam. Because the doors are so close to the fixture, the cut is fairly soft (Figure 3.9). Barn doors typically have two large leaves and two smaller triangular ones. When the bigger doors are horizontal, they are said to be "Chinese"; when vertical, "American." By closing the two large leaves into a narrow slit and folding the small leaves out of the way, you can make a narrow slash. The slash can be horizontal—for an eye light, for example—or turned diagonally to make a slash across a background.

Snoot

When a very confined, narrow, circular beam is desired, replace the barn doors with a snoot. Snoots come in various sizes, from wide (called a *top hat)* to very narrow *(stovepipe)*. Some snoots are fitted with four rings with different aperture sizes so that you can adjust the beam width (Figure 3.10). You might use snoots, for example, if you wanted to light a set with small pools of light—lighting tables in a café.

Focal spot

The focal spot attachment is a hold over from a time when Fresnel lights were pervasive in motion picture sets and ellipsoidal spotlights were not typically part of the lighting package. A focal spot essentially changes a Fresnel into a spotlight. The focal spot lens assembly creates a narrow, bright, even circle. Like an ellipsoidal reflector spotlight, a focal spot has framing shutters. It accepts design patterns called *gobos* and *mattes*, which can be projected and focused onto the scene. It has

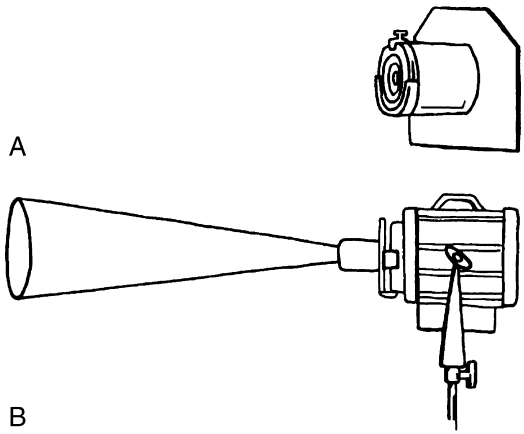

FIGURE 3.10

(A) A snoot with multiple aperture rings allows some flexibility in beam width. (B) A snoot confines the beam to a narrow circle.

interchangeable lens tubes—wide-beam and narrow-beam. It also comes with a gel ring to add color gels. A focal spot attachment is actually a very poor substitute for an actual ellipsoidal spotlight such as the Source Four discussed later in this chapter.

Shutters

Shutters are like heavy-duty louvers or blinds (Figure 3.11); they have rows of parallel slats that open and close. The shutter is mounted on the front of the light. The shutter can be controlled to smoothly reduce the amount of light getting to the subject. Shutters are handy when the light level needs to change during a shot. Care must be taken to avoid projecting a Venetian-blind pattern on the subject. Keep the light some distance from the subject and use diffusion material. Be watchful also for a vertical shift in the position of the beam as the shutters are closed. Shutters can be used to create a lightning effect; opening and quickly closing the shutter can produce a sudden flash. Use appropriate caution; the shutters will warp from the heat buildup if kept closed for too long.

20k and 24k tungsten Fresnels

For almost a century, the biggest single-source tungsten light was the 10k. The advent of 20k and 24k lamps (in 1998) paved the way for a variety of 20k and 24k fixtures, including Fresnel fixtures, skypans, and beam projectors. The 20k Fresnel lights typically have a large 30-in. Fresnel lens and are great for creating sunlight steaming in through windows when working on a sound stage, or for lighting a large area for a night exterior.

20k lamps are typically powered through a stand-alone dimmer. A dimmer is used to bring the lamp up to intensity more slowly than a switch does. These large lamps have a very high inrush current when started cold. The inrush current is hard on the lamp, and the lamps are expensive.

FIGURE 3.11

Shutters can be manually activated or motorized as shown here. These DMX512-controlled shutters are activated from a dimmer board or DMX512 remote slider.

(Courtesy Mole-Richardson Company, Los Angeles, CA.)

Lamps are now available in various voltages: 208, 220, 230, and 240 V. It is important to match the lamp installed to the voltage of the system you are using. A 208-V bulb will be stressed if 240 V is applied to it. Conversely, a 240-V bulb running on 208 V will not have as much output and will have a warm color temperature.

The lamp and its installation

Lamps are referred to by a three-letter code assigned by the American National Standards Institute (ANSI). For example, a typical 1k Fresnel uses an EGT bulb. ANSI codes are listed in Appendix B.

Most larger Fresnels used in motion picture work have a bipostal (two-pin) lamp base. Smaller lamps, such as the 200 W FEV, have a bayonet base. Bulbs are listed by base type in Table B.3. Figure 3.12 shows how to open up various models of lights to get at the globe.

On small units, the bulb simply plugs straight into the lamp base and is held in place by friction. When removing the bulb from this type of base, be careful not to break the glass off its porcelain base. Firmly grasp the porcelain base and wiggle the globe out. Do not handle the glass. On lights 2000 W and larger, a screw in the fixture's lamp base tightens the base around the pins of the bulb. The globe comes out freely when the thumbscrew is loosened.

The position of the lamp relative to the reflector is critical to the proper operation of the light. The filament of the bulb sits precisely at the focal point of the reflector. Therefore, if the bulb is not seated properly or the reflector is bent, the lamp's performance is drastically reduced.

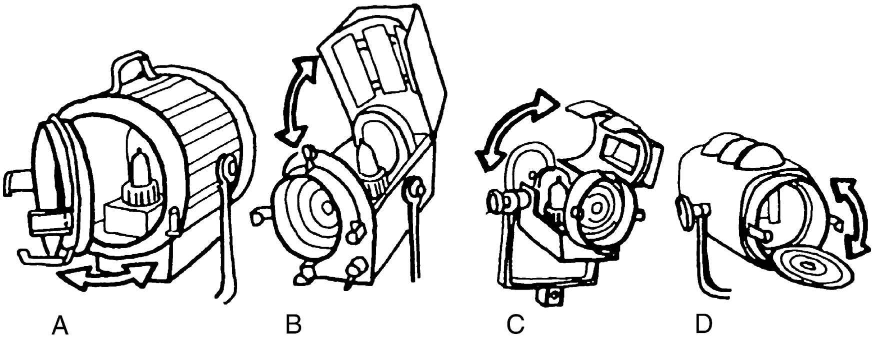

FIGURE 3.12

Four common ways to access the inside of a Fresnel fixture. (A) With most lights 1000 W and larger, the lens door swings open on a hinge. (B) On a baby-baby, the top of the housing swings back on a hinge at the back of the fixture. (C) The top of a Pepper's housing swings open to one side. (D) The lens of a midget is held in place by a metal tab. Push down the tab to take out the lens.

Tilt angle

To ensure proper heat dissipation, manufacturers recommend that Fresnels be hung with the base down. Each type of globe has a limit to the amount it can be tilted on its side without shortening the life of the globe. For example, a senior (a 5k Fresnel fixture) should burn with the bulb oriented within 45° of vertical. In addition to damaging the bulb, a 2000-W baby junior light hung at an extreme downward tilt will melt the reflector. In practice, the tilt angle is a concern only with lights that have large, expensive globes. Small lights are hung in whatever manner is required.

SOFT LIGHTS

Soft lights (Figures 3.13 and 3.14) are designed to produce diffused light with less-defined shadows. Light from the long tubular globes is directed into a white concave reflector. Because it is indirect, bounced off a diffuse white surface, and exits through a relatively large aperture, the resulting light is soft and has a wide, even, uncontrolled spread. Soft lights are commonly used for fill and general room ambiance.

Because soft lights use indirect light, they produce far less light per watt than Fresnels. Most soft lights have multiple globes, each switched individually, making it easy to increase or reduce the light's intensity. Figure 3.15 shows the egg crate and snoot, which can also be used to contain and control soft light. A gel frame is also a standard accessory. Soft lights do not generally have scrims, but you can improvise by inserting a baby scrim between the base and the white reflector surface, sandwiched with the egg crate and held in place with a grip clip.

To maintain maximum intensity and proper color temperature, the white reflector must periodically be cleaned or repainted. When repainting the interior surface, use "best boy white" paint. Best boy white reflects light without changing the color of the light and withstands high temperatures. If regular white paint is used, it will appear off-color.

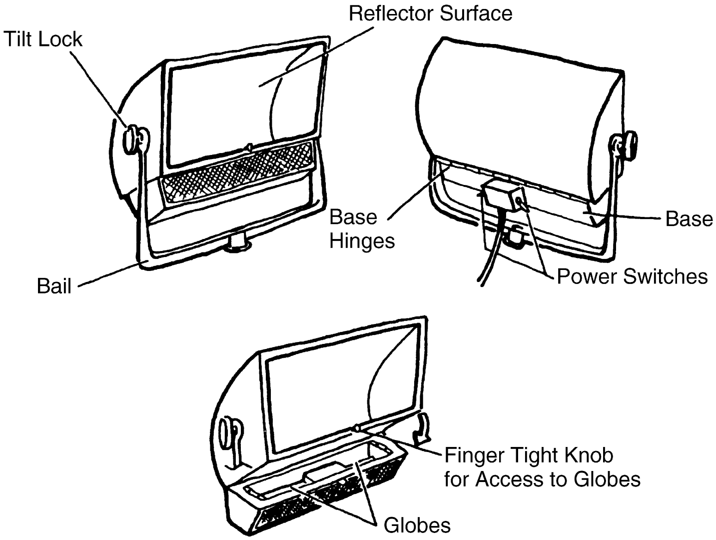

FIGURE 3.13

Anatomy of a 2k zip soft light.

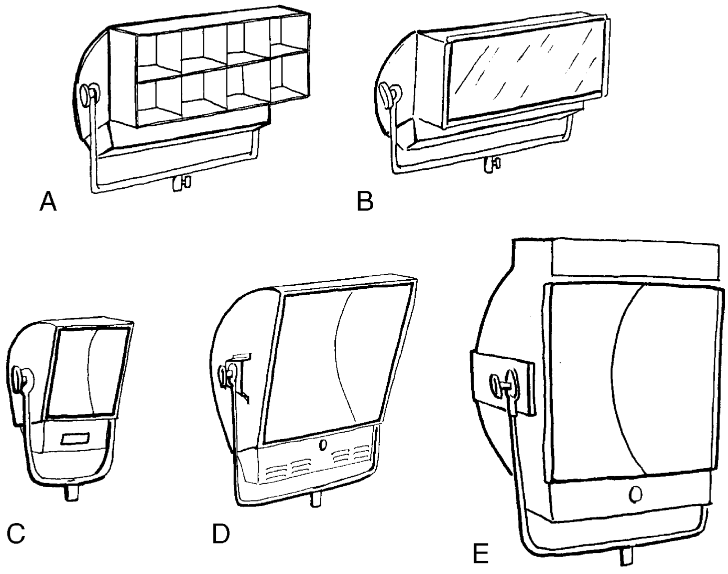

FIGURE 3.14

Soft lights and their accessories. (A) Egg crate: this black, metal grid helps control spill. It is a good idea to keep an egg crate with each soft light because they are used frequently. (B) Diffuser frame (shown here placed on the front of a snoot): this square gel frame fits in the front of the unit to hold colored gel or diffusion. (C) 750 W zip. (D) 4k soft. (E) 8k Softlite with eight 1k globes.

FIGURE 3.15

Barger Lite heads are designed specifically for a fabric softbox. It has some advantages over using a Fresnel or open-face fixture with a fabric softbox accessory. The head is lightweight, has a tilt lock designed to prevent sag (a common problem), and uses double-ended lamps in pebbled reflectors to evenly illuminate the entire diffusion. The multiple 650- or 1000-W lamps are individually switched for easy brightness adjustment. Barger makes their heads in various shapes and sizes: from a small 3-lamp fixture up to a 12-lamp 12 kW fixture.

(Courtesy Barger Lite.)

To gain access to the lamps, loosen the finger screws that lock the basket to the reflector and hinge the base open. The lamps are double-ended and held in place in a spring-loaded porcelain base. To install the lamp, insert one end and push back the spring until the other end can slide in.

"BAG" LIGHTS

Soft light is often created by shining a light through a frame of diffusion held by a C-stand; however, a bag light greatly reduces time and clutter on set because it essentially replaces diffusion frames and flags with a single lightweight, self-contained accessory that attaches directly to the front of a light. A fabric softbox or bag light (commonly known as a Chimera, which is the name of one manufacturer) is an accessory designed to create pleasing soft light by diffusing the light rays and enlarging the size of the source, while also containing the light between the fixture and the diffusion. Manipulating light in this way is discussed in greater detail in Chapter 6. Figure 3.15 shows a Barger Bag light fixture, a fixture designed specifically for a fabric softbox attachment.

OPEN-FACE LIGHTS

As the name implies, open-face lights have no lens. They are simpler, less expensive and less refined than Fresnels. The beam is not clean like a Fresnel. Light from an open-face light comes from two places, the lamp and the reflector, creating a double shadow line. Open-face lights make good

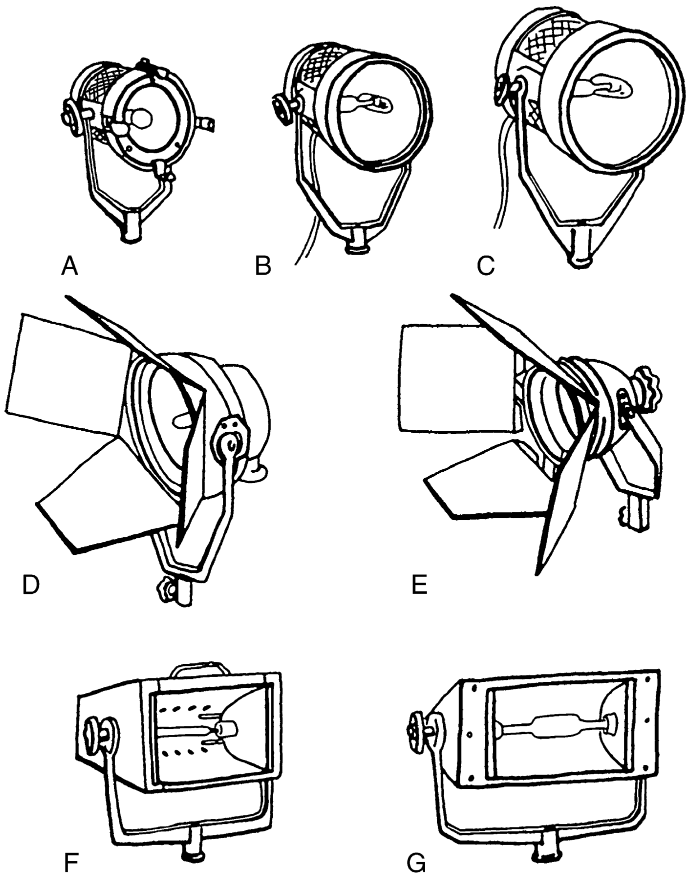

FIGURE 3.16

Open-face fixtures: (A) 650 W teenie-weenie, (B) 1k Mickey, (C) 2k mighty, (D) 2k blonde, (E) 1k redhead, (F) 1k broad, (G) 1k or 2k nook light.

bounce lights (directed into a white bounce surface) or can be handy for lighting elements of the background set. To be used for lighting actors, a medium to heavy diffusion is needed to blend the double source and take the garish curse off the light.

Open-face fixtures can be divided into three categories: prime fixtures, broads and nook lights, and portable kit lights. Figure 3.16 illustrates some open-face lights with which an electrician must be familiar.

Prime fixtures

Prime fixtures like those shown in Figure 3.17 use a double-ended lamp. They have a round face and an adjustable reflector for flood/spot control and come with barn doors and a scrim set. They are lightweight, durable lights with a relatively high intensity per watt and are more controllable than broads and nook lights. All sizes mount on a baby stud.

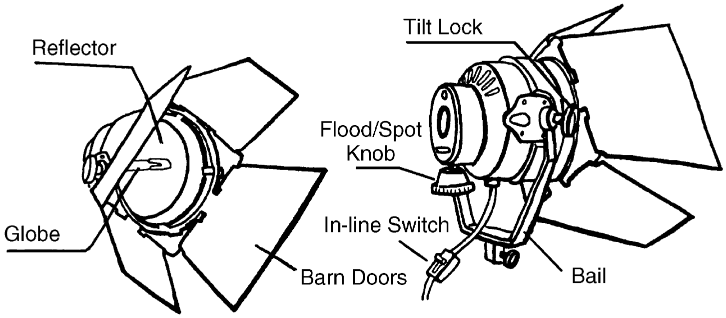

FIGURE 3.17

Anatomy of a blonde 2k open-face fixture.

Compared to the optical train of a Fresnel, an open-face light is pretty unrefined. The flood/spot mechanism alters the globe's position relative to the reflector (Figure 3.5B). When the globe is close to the reflector, the reflector sends out a wide beam; when the globe is pulled away from the reflector, it reflects more of the rays in a narrower beam. Open-face lights tend to spill light everywhere. To compensate, they need large barn doors.

Open-face prime fixtures are often bounced into a white surface such as foamcore to create soft light. Note that open-face lights tend to burn very hot and can melt a foamcore bounce board or destroy a flag if it is placed too close to the light. Think twice before rigging a light close to set pieces, and allow ventilation above the fixture.

Broads and nook lights

Broads and nook lights (Figure 3.16F and G) consist of little more than a long, double-ended bulb and a curved or V-shaped silver reflector. They are dirt-cheap and are small and light, so they can be more easily hidden in the set. Because broads and nook lights create raw, hard light, they tend to be used for jobs such as throwing light on a background, backlighting a large translucent set piece, or translight. They are also handy as work lights.

Light kits

Small, mobile camera crews for documentary, industrial, and promotional video and film work normally use portable open-face lights. The lights come in kits with a full complement of accessories, including adaptive, lightweight mounting hardware and lightweight stands. The units are small and usually draw 1000 W or less (Figure 3.18).

The quality of the light can be manipulated using gel frames to alter color or diffuse the light. Because the raw light from an open-face fixture is often hard and unattractive, cinematographers seek to soften the source, bouncing the light into silver umbrellas, or attaching a Chimera-type softbox to the fixture.

FIGURE 3.18

Lowel open-face lighting kit with accessories. The DP kit shown includes four 1k DP lights, stands, scrims, special barn doors, diffusion frames, mixed gels, color correction blue gels, a super spot reflector, a space clamp (special furniture clamp), a spare globe case, power cords, and extensions.

(Courtesy Lowel-Light Manufacturing, Inc., Brooklyn, NY.)

PAR LIGHTS

There are two distinct light designs that are commonly called pars: those that use a PAR lamp, and those that use a single-ended axially mounted lamp in a fixture having a parabolic reflector (Figure 3.5C and D). Both types are designed with the lamp filament placed at the focal point of a polished aluminum parabolic reflector, so that light is projected from the reflector in parallel rays. The rays then pass through a spreader lens, which can be very narrow spot, spot, medium flood, wide flood, or extra-wide flood (Figure 3.19). This optical design enables a very punchy, bright beam with more light output per watt than any other incandescent light. A single 1k PAR with a very narrow spot lens is as bright as a 10k Fresnel, but with a much smaller beam size.

In the late 1960s and into the 1970s, Mole-Richardson Company developed a large range of light fixtures for our industry, grouping PAR lamps together in arrays to make relatively inexpensive, yet powerful lights (Figure 3.20). Around the same time, PAR lamps were built into “cans” and became the central fixture of the rock and roll industry (Figure 3.21). Par arrays and par cans both remain vital instruments in our lighting arsenal today.

PAR lamps

All of the optical parts of a par light are contained within the PAR lamp itself. The filament envelope, lens, and reflector are one permanently sealed unit, like an old-fashioned car headlight (Figure 3.19).

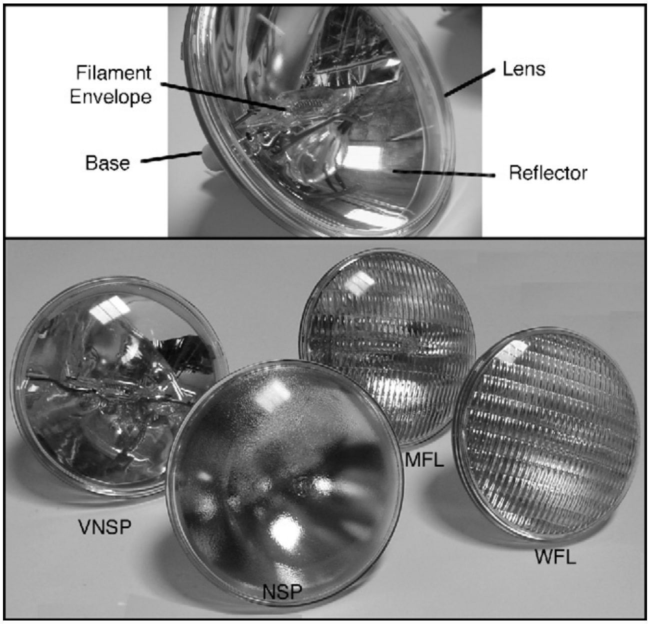

FIGURE 3.19

Anatomy of a PAR lamp. The lens types from left to right are very narrow spot (VNSP), narrow spot (NSP), medium flood (MFL), and wide flood (WFL). (Extra-wide flood, XWFL, is not shown.)

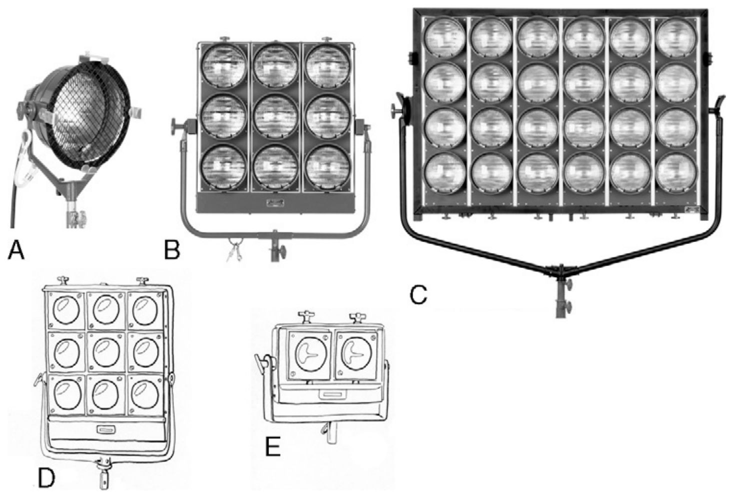

FIGURE 3.20

In the Molepar fixture (A), the lamp rotates to allow adjustment of the elliptical beam. The Maxi-Brute (B) offers three pods of three lamps each. The two outside pods can be panned individually. The Moleeno (C) and similar Dino light arrays have 24 or 36 lamps. Because they can be lamped with any of the lenses shown in Figure 3.19, PARs offer a lot of flexibility and punch. The most commonly used FAY lamps (smaller 650 W lamps) are the nine-light FAY (D) and two-light FAY (E).

(Courtesy Mole-Richardson Company, Los Angeles, CA.)

FIGURE 3.21

Par cans come in black, white, or chrome finish.

(Courtesy Mole-Richardson Company, Los Angeles, CA.)

PAR lamps are available in a variety of sizes, the two most commonly used in our business are 8-in diameter PAR 64 lamps (500-1000 W) and 4 1/2-in diameter PAR 36 lamps (typically 650 W). For PAR lamps the number is the diameter of the lens in eighths of an inch. For example, a PAR 64 is 8 inches in diameter (64/8 = 8-in). For any size PAR light there are a wide variety of different lamps: a range of spreader lenses, wattages, and color temperatures. The most common size is the 1000 W PAR 64. PAR 64s are available in various wattages from 100 to 1200 W, and with various spreader lenses. (See also Tables B.4, B.5, and B.6.) Medium flood and wide PAR lamps tend to have an elliptical beam rather than a circular one. The lamp can be turned in its fixture to orient the beam as required.

For an even narrower, very intense beam, an aircraft landing (ACL) light can be fitted into standard PAR 64 housings. ACL lamps operate on 28 V but can be wires in series in gangs of four and connected to a 120-V circuit.

PAR 64 and PAR 36 lamps are also available with a dichroic reflector that absorbs much of the yellow light and reflects a color temperature closer to daylight (about 5000 K). Dichroic reflector PARs were developed as daylight sources before HMIs became predominant. “FAY” lamps are daylight-balanced PAR 36 lamps (5000 K, 650 W per bulb) (see Figure 3.20D and E). Using a dichroic PAR lamp gives better light output than using a blue gel on the light, but of course,

HMIs are far more efficient, and preferable. Nonetheless dichroic PAR lamps offer an inexpensive alternative that may suffice for some situations. Bulb designations are listed in Appendix B. It is increasingly difficult to get dichroic PAR lamps, and the lamps run more than $130 each to buy (compared to $35 for a normal PAR 64 lamp), so if you get them on rental, take care not to lose or break them.

Par cans

Par cans are simple, lightweight, inexpensive, maintenance-free with no moving parts, and made for the heavy-duty life of the concert tour (Figure 3.21). Their design is as simple as they come—a PAR lamp mounted at the back of a coffee can-like cylinder with an extended snoot and a gel frame slot at the front. Par cans generally do not come with scrims (in concert lighting they run on dimmers). The gel frame of a par 64 is typically 10 in. in diameter and any 10-in. scrim (Mighty-Mole) fits the slot. Par cans come in many sizes. The 1k PAR 64 is the most useful for lighting; the smaller PAR 56, 46, 38, 36, and 16 sizes are sometimes used as on-camera set decoration, as venue lights, and to light art work or architecture.

Par cans are the workhorse of rock-concert lighting, because they can drive light through even the most saturated gel colors. Narrow-beam pars can pound light onto a performer or produce strong shafts of light in the atmosphere. The wider-beam pars fill the stage with a wash of color. In motion picture and television work, narrow pars are often used to splash a bright streak of sunlight across a part of the set or to bounce light off the floor. Because the narrow spot globes are so punchy, pars are ideal for creating a strong water reflection effect (e.g., the moving light off a swimming pool). They can also throw light long distances, which is handy, for example, for lighting foliage or buildings at night. The light they produce is hard and unpleasant when used directly on faces, but bouncing a par into a light-colored surface near an actor can create a beautiful glowing light. Stunning examples of this effect can be found in the work of Robert Richardson, ASC (in *Casino, JFK*, and *Natural Born Killers*). Richardson creates beautiful dramatic scenes by bouncing a very narrow par (VNSP) off the tabletop in front of an actor, then obscures the tabletop from the camera with set dressing. Another great example is the beautiful naturalistic work of Conrad Hall, ASC in *Searching for Bobby Fischer,* in which he used pars to create beautiful bright sun splashes that glow on actors' faces and in their eyes.

Molepars, master lite, cine-queen

The Molepar (Figure 3.20A), Master Lite, and Cine-Queen are essentially PAR 64 lamp housing with ears to hold barn doors and scrims. The main difference, in practice, between a par can and a fixture like a Molepar is spill. An open fixture like a Molepar tends to spill light in all directions. Spill can be managed with blackwrap and barn doors, of course.

Par arrays

Arrays of PAR lamps (Figure 3.20B and C) are commonly used for strong directional light. They are manufactured with 1, 2, 4, 6, 9, 12, 24, and 36 lamps. The most common is the nine-light PAR 64 fixture known as the Maxi-Brute (Figure 3.20B). The 24-lights are known as Dinos, or Mole's version, Moleeno (Figure 3.20C). The 36-light unit is a Super Dino. The rest are referred to by

the number of lights in the cluster—for example, a four-light, six-light, or—most common—a nine-light. *Mini-brute* or *nine-light* refers to the smaller PAR 36 nine-light (Figure 3.20D).

Large par arrays can put out a lot of light. They are often used to light large spaces at night or bounced into a 12 × 12-white griffolyn (a durable white reflective plastic tied taught across on a large aluminum frame) for soft fill. A nine-light works well as a bounce light, because you can adjust the intensity quickly by snapping lamps on or off. On a sound stage in large exterior sets, multiple par arrays can create a dominant direction of light to simulate sunlight.

Par arrays are designed in rows, or *pods*, of three to six lights. The pods are mounted into a metal frame held in place at the ends. Usually, the pod can be swiveled and tightened with a knuckle at one end. This affords them some versatility. The pods can be individually focused—splayed out to cover a large area or focused to concentrate light in a smaller area. Additionally, the gaffer can have the fixture fitted with any kind of PAR lamps, from wide flood to very narrow, or can use a combination, as desired. One may even choose to mix color temperatures by including dichroic lamps. Relamping a large par array is time-consuming—something you want to take care of well ahead of time.

The ARRI Ruby 7 is a unique arrangement of seven PAR 64 globes mounted in a circle that hinges from the outside ring, so the beams can be made to converge at a selected distance, diverge into a wide flood, or unite into one powerful parallel beam (Figure 3.22).

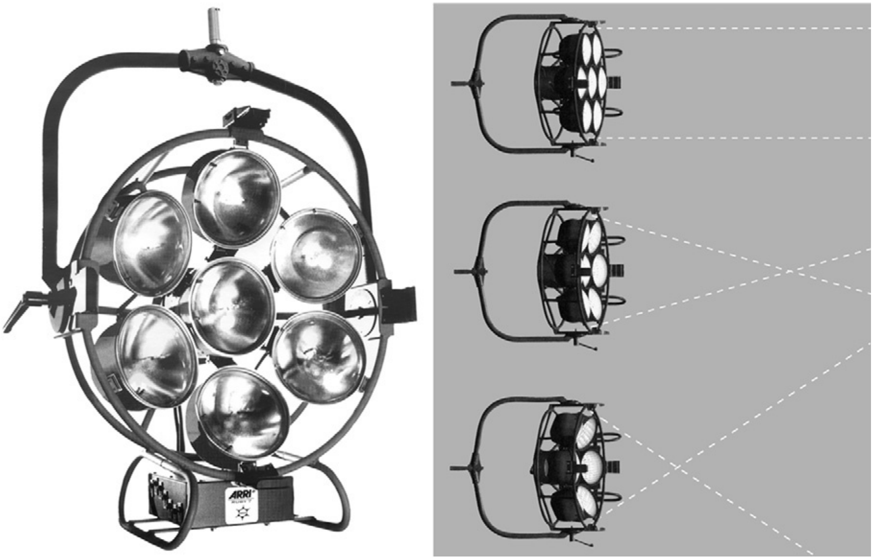

FIGURE 3.22

The ARRI Ruby 7 is a unique seven-light PAR 64 array with flood spot control (the knob is located on the back of the fixture). The seven on/off switches are on the base.

(Courtesy ARRI Lighting, New York.)

Axially mounted par fixtures

The highest-wattage PAR lamp is 1200 W. It wasn't until several years into the new millennium that Mole-Richardson started using axially mounted tungsten lamps (specially designed by GE) in a fixture with a parabolic reflector. Mole calls these lights Tungsten Pars (Figure 3.23A). This design finally enabled wattages of 2000, 5000, and 12,000 W for incandescent parabolic reflector lights. The 12k par is comparable in light output to a 20k Fresnel, but uses 60% less power, and produces 60% as much heat. With the Tungsten Par, the lenses are fitted to the front of the fixture and can be changed at will. The lights have four available lenses, narrow, medium, wide, and extra-wide. These fixtures also allow for adjustment of the lamp in the reflector. This is not really flood-spot control. It is used to fine-tune the evenness and brightness of the beam. Accessories include scrims and barn doors.

ETC makes an extremely efficient axially mounted par lamp called the Source Four Par (Figure 3.23B). Using ETC's renowned HPL lamp technology this light can achieve, with a 575-W lamp, light output comparable to a 1000-W PAR 64. If you use the 750 W lamp, the output is superior to any 1k PAR lamp. The 3250-K color temperature lamps come in sizes of 750, 575, and 375 W. The lamps also come in a 3050-K long-life version with four times the lamp life (1500-2000 hours as apposed to 300-400 hours for the 3250 K lamps). Lenses include VNSP, NSP, MFL, WFL, and an optional XWFL. Optional accessories include top hat snoot (gel extender), concentric ring snoot, and barn doors.

FIGURE 3.23

Par lights with axially mounted lamps: (A) Mole-Richardson makes Tungsten Pars at 2k, 5k, and 12 kW. The 12 kW Tungsten Par shown here uses 208 V power, drawing about 57 A per phase. It comes with a set of five interchangeable lenses, and has brightness equivalent to a 20 kW Fresnel. (Courtesy Mole Richardson Co., Los Angeles, CA); (B) ETC's Source Four Par.

(Reproduced by permission of Electronic Theatre Controls, Inc.)

Another light design using axially mounted lamps to advantage is the Mac Tech Tungsten, made by B&M Lighting. The Mac Tech 6-, 9-, and 12-light arrays look like traditional par arrays, but they use axially mounted lamps rather than PAR 64 lamps to reduce weight and lamp cost. Mac Tech uses compact-filament lamps (HPL, SPH, or GL) in an 8-in. parabolic reflector. The Mac Tech 12-light weights 60 pounds, just over half as much as a traditional par array, because it does not use PAR lamps and because the frame is aluminum, not steel. This allows four 12-light fixtures to be mounted in the basket of an aerial lift (such as a telescoping boom arm lift, common used as a lighting platform what lighting large areas) without exceeding the basket's weight limitations. This is equivalent to a 48-light Dino, but drawing 300 amps instead of 400 amps.

Five different spreader lenses are available: very narrow spot, narrow spot, medium flood, wide flood, and very wide flood. A dichroic glass filter is also available, which gives the option for tungsten or daylight color balance with a single light. A special Chimera arrangement is available for the Mac Tech 6, which makes it a very bright large soft source. The larger arrays can also be fitted with ear extensions to hold diffusion. The lights are available with multipin (Socapex) connectors so that the six lamps can be controlled individually, or with Bates connectors.

ELLIPSOIDAL REFLECTOR SPOTLIGHTS

The ellipsoidal reflector spotlight (ERS) has long been the dominant light fixture used to light stage productions. It is also known as an *ellipsoidal*, or *profile spotlight*, or by trade names such as *Leko* or *Source Four*.[3] Ellipsoidal spotlights (Figure 3.24) were originally designed to give the theater lighting designer the strong throw, versatility, and control needed to light specific areas of the stage, blend the beam edges of adjoining areas seamlessly, and shape the beam to cut light from spilling where it is not wanted. Naturally, these fixtures are often employed when filming stage performances, but their special qualities are also very handy in other situations. A Leko can make a hard cut where there is no room to make a hard cut with a flag. For example, when an actor answers her front door, she is basically up against a wall with no space to fit a fixture to light her face. She can be lit easily with an ellipsoidal spotlight aimed into a piece of white show card taped to the inside wall beside the door. An ellipsoidal can make the hard cut necessary to prevent direct light from hitting anything but the card.

An ellipsoidal spotlight is able to project a beam that can be shaped by shutters, an iris, and a gobo pattern (Figure 3.25A). The shape of the beam is determined by the shape or pattern in the gate aperture. Light collected from the elliptical reflector passes through the gate; a lens assembly in the barrel then brings the shape or pattern in the gate into focus (Figure 3.5E). The gate can be brought into sharp or soft focus by sliding the lens barrel forward or backward.

The four cutting *shutters* (top, bottom, left, and right) can be pushed into the path of the beam to shape the beam edges it into a square, rectangle, or whatever shape is needed. Immediately in front of the shutters is the *gobo* slot. The gobo pattern holder fits into this slot. Hundreds of gobo pattern templates are available, including a wide variety of window and Venetian blind patterns, foliage

[3]Leko is the trademark of Strand Lighting but is widely used to refer generally to ellipsoidal spotlights. Source Four, made by ETC, is the most common ERS.

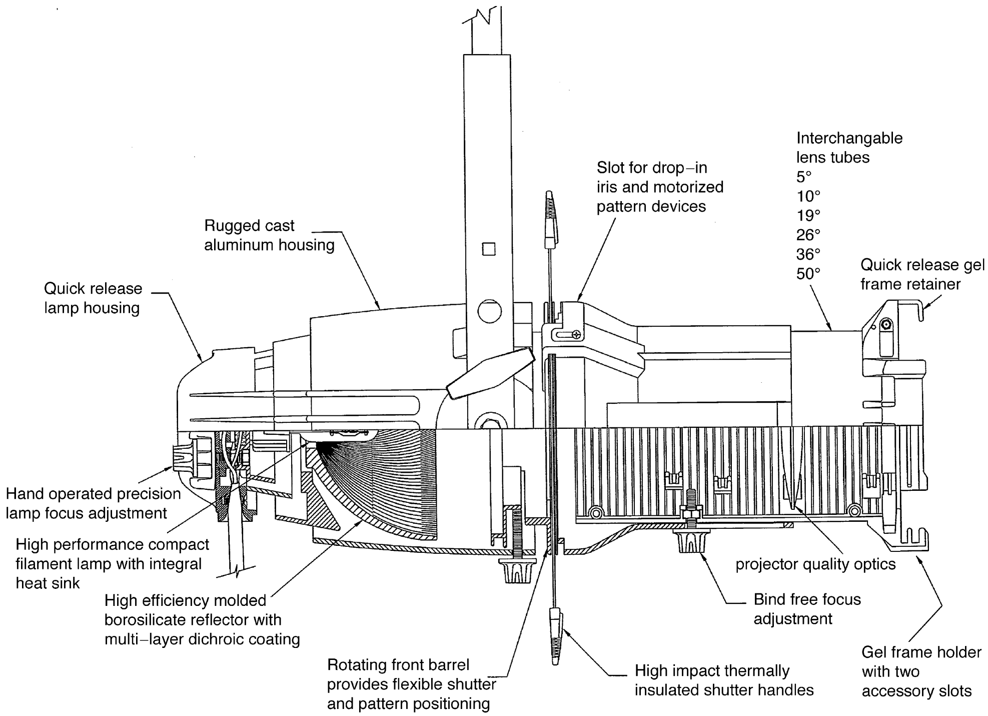

FIGURE 3.24

A cut-away view of the Source Four. Innovative advances in the design of the bulb, reflector, and lens assembly allow this 575 W light to outperform standard 1k ellipsoidal, while providing exceptionally sharp shutter cuts without halation, even distribution of light through the field, extended pattern life, and eliminating shutter jams due to heat warping. You can put two Source Fours on a 1.2 kW dimmer circuit, doubling the dimmer capacity. Source Fours also take an even brighter 750 W lamp.

(Reproduced by permission of Electronic Theatre Controls, Inc.)

FIGURE 3.25

(A) The gobo pattern not only projects a pattern, but also breaks up the beam, which will be visible if there is a little smoke, fog, or atmosphere in the air. This photo shows one of the standard gobos of a Mac III Profile moving light.

(Courtesy Martin Professional.)

Continued

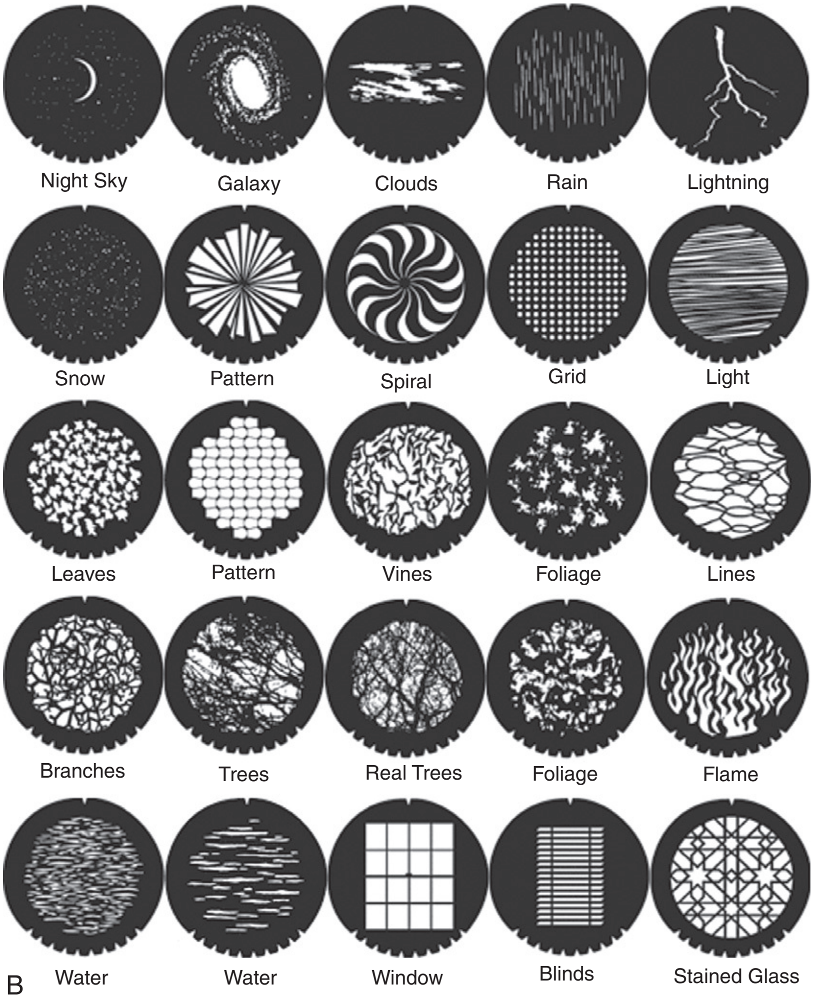

FIGURE 3.25—CONT'D

(B) This figure shows a small sample of the literally hundreds of gobo templates available.

(Courtesy Lee Filters.)

patterns, clouds, cityscapes, stars, flames—practically anything you can name (Figure 3.25B). Gobos are also available that are made of glass enhanced with color. Gobo manufacturers often provide materials on their Web sites showing the many extraordinary effects that can be created by layering color and gobo effects. The entire barrel section of the light fixture can be rotated to help in aligning shutter cuts or gobo patterns.

A second larger slot accommodates an iris, gobo rotator, or other accessories. The iris handle closes the leaves of the iris, shrinking the radius of the field.

The Source Four may be used with any one of many interchangeable fixed-focus lenses as shown in the following table. Source Fours are also available with permanently fitted zoom lens, which allows quick adjustment of the beam diameter and intensity. The narrower the beam angle of the lens, the greater the throw and intensity and the smaller the field. If you needed to project a gobo and fill a screen with only limited space, you could use the 70° or 90° lens to do so. On the other hand, if the light has to work far away from the performer, or if the beam has to be small and intense a 14°, 10°, or even a 5° should be used.

Source Four Lenses

By Field Angle (Degrees of Spread)	Equivalent Lens Diameter and Focal Length
Standard lenses	
5°	
10°	
14°	
19°	6 × 16
26°	6 × 12
36°	6 × 9
50°	4½ × 6
70°	
90°	
15°–30° Zoom	
25°–50° Zoom	
Enhanced Definition Lens Tube (EDLT)	
19°	6 × 16
26°	6 × 12
36°	6 × 9
50°	4 ½ × 6

Some manufacturers refer to individual fixtures by lens diameter and focal length (6 × 9 in. has a 6-in. lens and a 9-in. focal length). Although these are commonly used terms in theatrical lighting, gaffers often scratch their heads when they see these figures, not knowing which type works for a given application, but you can easily calculate the beam diameter and light intensity of any fixture using data given in Appendix A. Generally speaking, wide-beam Lekos of 250 and 500 W are used above-stage in small theaters, 750 and 1000 W 6 × 9 and 6 × 12 fixtures are used above-stage and in the front of the house in medium-sized theaters, and 6 × 16 or 8 × 16 1k and 2k fixtures are used for long throws from the house.

Lamp adjustment and installation

The lamp of the Source Four may require adjustment if it gets out of center alignment, or if you wish to change the evenness of the field. Normally, the lamp is adjusted to create a completely even field, but this adjustment allows the user to increase center brightness at the cost of an even field, when such an effect is desired. On a Source Four, the rear lamp housing has two concentric adjustment knobs: the outer one centers the lamp; the inner knob adjusts the flatness of the field (Figure 3.26A). A "flat field" is as even as possible, all the way to the edges. A "peak" field is as bright as possible and less flat.

To center and adjust the lamp:

1. Aim the light at a flat surface, so you can clearly see the field.
2. Loosen the outer knob on the rear of the lamp housing.
3. Gently move the outer knob left, right, up, and down until the lamp is centered in the reflector.
4. Tighten the outer knob (clockwise) to lock it in position.
5. Turn the inner knob either clockwise or counterclockwise until you find the optimum flat field.

To change a burnt-out bulb:

1. Remove the back of the lamp housing by loosening the knurled bolt on the back of the housing and lifting out.
2. Hold the lamp by the base. (Do not touch the glass. If you accidentally smudge the glass, clean it with rubbing alcohol and a lint-free cloth.) Note: lamps come in 115 and 120 V in the United

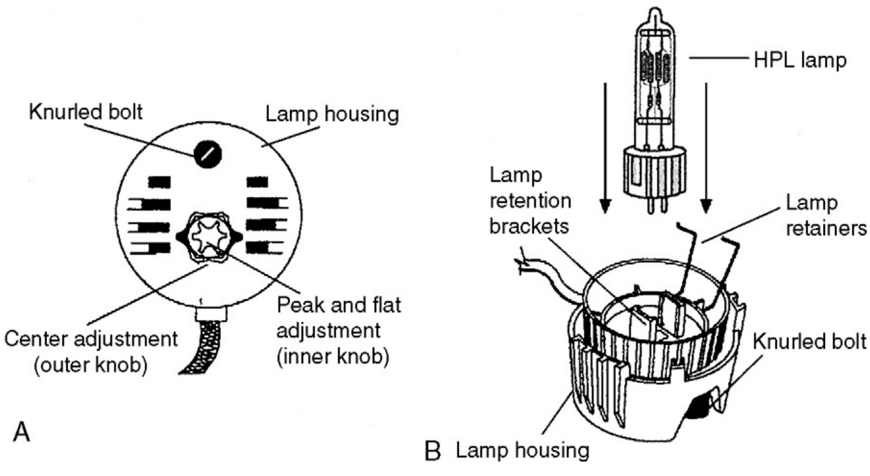

FIGURE 3.26

(A) The outer knob centers the lamp; the inner knob adjusts the flatness of the field. (B) The lamp base, lamp, and retention bracket.

(Reproduced by permission of Electronic Theatre Controls, Inc.)

States. They are also available in different color temperatures (the 3050 K bulbs last quite a bit longer that the 3200 K bulbs).

3. Line up the flat sides of the lamp base with the retention brackets on either side of the socket.
4. Push the lamp into the base until it seats firmly. The top of the lamp base should be even with the top of the retention bracket (Figure 3.26B).
5. Press the lamp retaining clip across the lamp base to secure the lamp in place.
6. Reinstall the lamp housing by aligning the bolt hole and tightening the knurled bolt.
7. Center the bulb and adjust the field flatness, as described previously.

Detailed information about how to clean the lenses and reflectors, as well as the many adjustments that can be made to these fixtures, is available on the manufacturers' Web sites.

Theater and concert lights usually come ready to be hung in a theater, with a pipe clamp bolted to the bail and a short-tail power cord with a 20 A Bates connector. When ordering theatrical lights, be sure to order *bail blocks* and Bates-to-Edison *pigtail adapters* to adapt the fixtures for your use (on stands with an Edison outlet box). A bail block bolts to the bail in place of the pipe clamp and typically fits both baby and junior stands.

Ellipsoidal spotlight accessories

Gel frames, gobo pattern holders, and irises are pretty standard accessories for film work. A wide variety of other accessories are available for ellipsoidal fixtures, many of them invented for and used principally in theatrical applications; however, they can offer conveniences, cost savings, and useful effects for film work, too.

Donuts and hats

A donut is a metal mask that slides into the gel frame slot. It is used to sharpen gobo patterns and clean up color fringes at the beam edge (at the expense of some light output).

Enhanced definition lens tubes

The pattern used in the gobo slot can be quite detailed and complex. For example, often a company will have its company logo made into a gobo for projection at presentations or trade shows. For the purpose of image projection, ETC has developed Enhanced Definition Lens Tubes (EDLTs) for the Source Four. One can replace the lens tube of any Source Four with an EDLT. These lenses create an extremely sharp projection beam and increase field lumens and contrast so that even fine detail in a pattern is resolved clearly. Gaffers sometimes use EDLTs when the beam edge requires maximum sharpness, or when a detailed gobo has to be really sharp.

Follow spot adaptation

City Theatrical makes a follow spot retrofit for the Source Four (Figure 3.27A). The Source Four is commonly used as a follow spot in film work, and this retrofit which includes a followspot yoke, operating handles, and other refinements, makes it operable in a completely professional manner. These professional upgrades increase the mass of the fixture for smoother pan and tilt and to allow the light to be balanced at its center of gravity.

FIGURE 3.27

(A) A Source Four retrofitted for use as a fully functional follow spot, including a heavy duty follow spot yoke with professional pan bearings, handles for front and back of the fixture, and even a mini boomerang color changer or manual color scroller (not shown). The back handle acts as a counterweight for the color changer. (Courtesy City Theatrical, Inc.) (B) Film/FX scrolling gobo pattern. (Reproduced by permission of GAMPRODUCTS, INC., Los Angeles, CA) (C) Rosco I-cue Intelligent Mirror. (Product image supplied by Rosco Laboratories, Inc.) (D) Auto Yoke moving yoke for the Source Four. (Courtesy City Theatrical, Inc.)

Gobo rotator

A gobo makes a fixed pattern of light. A gobo rotator fits in the iris slot in front of the fixed gobo and employs a small 24 V variable-speed motor to put the pattern into motion. When a static gobo and moving gobo are used together, the motion of the rotating gobo animates the static gobo, creating shifting patterns and shimmering and twinkling light effects. For example, a rotating spiral pattern placed in font of a fixed break-up pattern creates radiating ripples of light from the center outward (or if the motor turns the other way, the ripples move inward). The GAM Web site offers online software to preview the effects any combination of their gobo patterns. There is an iPhone app that also allows you to play with defocus and spin speeds of gobos. Some gobo rotators allow two counter-rotating gobos (Rosco Vortex 360, GAM Twin-Spin), which provide a more abstract and less transparent effect. Some rotators can add to the possible effects by doing more than just spinning the gobo. A rotator such as the Apollo Roto-Q DMX is indexed so that a particular gobo position can be repeated. It can rock the gobo back and forth, swing, stutter, whip, stagger, shake, and clock (rotating and stopping at every five-minute mark around the clock). The two gobos are not quite on the same plane of focus. Experimentation with rotation speed and lens focus often helps improve the effect. Adding layers often helps disguise the simple mechanical nature of the effect, and it becomes more random and compelling. For example, you can cut different colors of gel and tape them together in the gel frame in conjunction with a moving light effect. A great deal of craft and finesse goes into successfully creating gobo effects. Often an effect will start off looking a little theatrical and amateurish, but further tweaking and experimentation cultivates something really nice. The gobo rotator typically uses a Power/DMX 24 VDC power supply, and controlled via DMX512.

Linear gobo FX

Gobo rotators create moving light effects that spin; there are also several types of effects generators that are designed to create lighting effects in linear format. This is used for creating flames (that lap upward), rain or snow (falling), ripples, or clouds, for example. In film and television, there are many possible applications for lighting effects such as this. For example, a cloud effect can be used to create moving reflections in the car surfaces for poor man's process or rear-screen projection shots.

An effects generator like the Film/FX device (from GAM; see Figure 3.27B) moves gobo cutouts continuously in a linear direction on a loop using a variable-speed motor. The device slides into the iris slot. There is enough space between the two sides of the loop that the side that is in focus provides the dominant direction of movement, while the other side, moving the other direction, animates the dominant pattern. GAM makes more than a dozen interchangeable pattern loops for the unit. The unit comes with a variable-speed control unit.

Another way to create a linear animation is to use a very large gobo wheel, of which only a portion passes through the light, thus appearing to be linear. The EFX Plus[2] (by City Theatrical) offers two planes of individually controllable linear motion, employing two 14-in. disc gobos. Gobo include a range of cutout patterns as well as art-glass patterns, for a very wide range of possible effects. Control is via DMX512. The unit is designed specifically for the Source Four and requires a modification of the light.

The Infinity Gobo Animation Device made by Rosco also employs a choice of several large 16.5-in. circular gobo wheels; however, this device is fitted to the gel frame slot at the front of

the light, not in the gobo slot. Placed here, the gobo pattern is out of focus, and serves to animate the fixed gobo that is at the plane of focus. This is another way to create flame and water ripple effects, or to animate foliage patterns

Motorized iris

The iris can be DMX512-controlled using a stepper motor device such as the Apollo EZ Iris DMX. It is controlled and powered via Power/DMX.

Color scroller (or color changer)

As the name indicates, a color scroller holds colored gel in a long scroll. A scroller such as the Apollo Smart Color 5.25 holds 16 different colors on the scroll. DMX512 is used to select which color is brought in front of the light. The color scroller is inserted into the gel frame holder at front of the light fixture. Power/DMX 24VDC powers the unit.

Color mixing

The SeaChanger is a color engine that uses variable amounts four dichroic filters (cyan, magenta, amber, and green) to create almost any color; it can do this dynamically (as a color cross-fade), and the color is not subject to fade as gels are. The SeaChanger is installed in the midsection of the Source Four between the lamp section and the lens section (the yoke is removed from the lamp and attached to the SeaChanger). The unit is powered from a 110-250-VAC source (non-dim). Control is via a standard DMX512 5-pin XLR connector, and uses four DMX channels. The SeaChanger is RDM-enabled. Almost any color can be created with three of the four colors (cyan, magenta, and amber). The green filter extends the color gamut; however, this color disk can be exchanged for either a douser (for fades without dimming) or any dichroic color.

Moving mirror remote

A moving mirror (motor drive mirror) attaches to the rear gel slot of a Source Four and provides remote control of pan and tilt, much like an automated light, but at a fraction of the price. The Rosco I-Cue Intelligent Mirror (Figure 3.27C) can accomplish 230° of pan and 57° of tilt. It is controlled via DMX512 protocol through a 4-pin XLR (Power/DMX system). It can be set for either 2-channel 8-bit resolution, or 4-channel 16-bit resolution. The I-Cue can also be put in automatic mode (with no DMX connection). It is assigned parameters manually using the menu on the unit, and automatically pans and tilts continuously between two positions.

Moving head

A moving-light base such as Auto Yoke (City Theatrical; see Figure 3.27D) or Right Arm (Apollo) provides DMX512 remote control to pan a Source Four 340° and tilt 270°. It plugs directly into 90-260 VAC (auto select). Control is via a standard 5-pin XLR DMX512.

Daylight lamp base

The Source Four fixture can be fitted with a MSR lamp housing (Joker Bug and others), to create a daylight-balanced light source with all the admirable control qualities of the Source Four (except dimming).

POWER/DMX

Some ERS accessories are fed 24VDC power and DMX512 control signal using a single 4-pin XLR cable. This arrangement is not in accordance with the DMX512 standard, but it provides convenience by feeding multiple accessories from a single Power/DMX power supply. Typically, pins 1 and 4 provide 24VDC, and pins 2 and 3 provide DMX512 (although some devices are set up differently, so the compatibility must be checked). The control signal is fed to the power supply using the standard DMX512 5-pin XLR connector. The power supply proves IN and THRU connections for this signal. The power supply then provides 4-pin XLR outputs to feed signal and power to the accessories connected to it. The 4-pin XLR may be daisy-chained to multiple devices. The total wattage of these devices cannot exceed the wattage of the power supply. Power supplies are available for a single accessory or multiple accessories. Typical power supply wattages are 60, 150, 300, and 600 W. The following list gives you an idea of how much power is consumed by various accessories:

Apollo Smart Color Scroller: 38 W
Apollo MXR Color Mixing Scroller: 43 W
Apollo Smart Move DMX: 13.5 W
Apollo Smart Move Vertical: 13.5 W
Apollo Roto-Q DMX: 12 W
AC Lighting Chroma Q Broadway: 22 W
AC Lighting Chroma Q M1, 2, 5, 8: 36 W
City Theatrical DMX Iris: 8.5 W
DHA Twin DMX: 12 W
Gam DMX Twin Spin: 14.4 W
Gam SX-4, 6 Gobo Tray: 10.8 W
Rainbow 6″, 8″, 12″ Pro Color Scroller: 14 W
Rainbow 15″ Pro Color Scroller: 29 W
Rosco I-Cue Mirror: 17 W
Rosco DMX Rotator: 6 W
Wybron Forerunner: 14 W

(For more about DMX512 and optical isolators, see Chapter 11.)

DEDOLIGHTS

Dedolights (manufactured by Dedotec) are small, compact fixtures that use two specially designed lenses in an assembly that is more efficient than a Fresnel and that provides a hard, adjustable beam with exceptionally even light across the field (Figure 3.28). In set lighting, the DLH2 kit has become an important part of the equipment package. This kit includes three 100 or 150 W fixtures, a power supply, cables, and accessories.

The special lens assembly gives the fixtures punch for the long throw and an unusually wide range of adjustment (the DLH2 model ranges from 40° in full flood to 2½° in full spot). A 100-W Dedolight has roughly the same light output as a 300-W Fresnel. The lights are so small, lightweight, and unobtrusive that they can easily be hidden in the set.

The lights have various accessories, including barn doors, gel frames, lightweight mounting hardware, suction mounts, camera clamps, and a focal-spot-like projection attachment. The projection attachment allows extremely precise control of the beam. It can be shuttered in on a beer label, for instance, providing a hard edge cut with no color fringing or softness around the edges. For this reason, the lights are useful in tabletop setups and miniature work.

FIGURE 3.28

The refined beam of a 100-W Dedolight.

(Courtesy Dedotec USA, Inc., Lodi, NJ.)

The 100-W Dedolights run on 12 V. The 150-W version runs on 24 V. The power supplies power to three, four, or five lights at a time. Three power settings are on the power supply for each light: high (3300 K, maximum light output), medium (3200 K, medium light output), and low (about 3000 K, lower light output). The lights can also be powered directly off a 12-V battery belt.

Dedo's 400 series lights are larger versions with the same optical technology. The DLH436 (400 W) runs off a power supply at 36 V. The low voltage allows the fixture to use a small lamp, which can be precisely collimated by the lens assembly. The power supply can be switched to different color temperatures (3200, 3400, or 3600 K). The DLH 650 (650 W) runs off the main power with no separate power supply. The DLH400D is a 400-W daylight fixture.

The Dedocool is a 250-W tungsten-balanced light designed for lighting small areas when a great deal of light is needed (e.g., for an extremely high shutter speed). Used at close range, the light can provide 220,000 FC at 8-12 in., while giving off very little heat. Insects, plants, food, plastics, paper, and other such items that would be adversely affected by the heat of any other source of this intensity can be filmed using this light. A cooling fan at the back of the fixture is necessary to cool the bulb. The special power supply keeps the fan running for a short time after the light is turned off to cool the light. If the light is unplugged while hot, damage to the fan can result.

BEAM PROJECTORS

The beam projector (BP) has been around since before movies were invented. Though they are commonly used in theater lighting, until their recent revival, they hadn't seen too much action on the silver screen. In 2000, Mole-Richardson redesigned the BP in large sizes for use in motion-picture work, and they have proved to be a valuable tool (Figure 3.29). The lamp in a BP is set in front

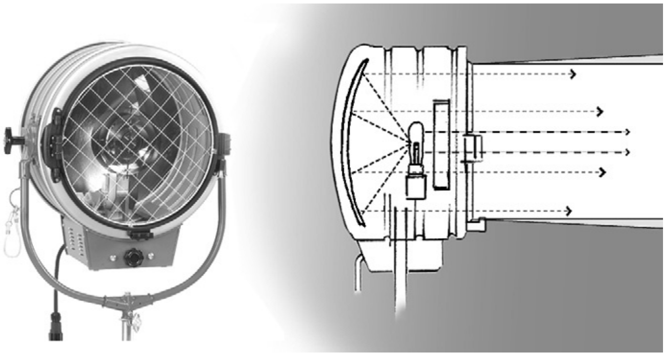

FIGURE 3.29

Beam projectors. The fixtures come in several sizes: an 18-in. fixture, either 2k tungsten or 1.2k HMI; a 24-in. fixture, either 5k tungsten or 2.5/4k HMI; and a huge 36-in. fixture, either 10k or 20k tungsten or 12k HMI.

(Courtesy Mole-Richardson Company.)

of a large parabolic glass mirror, which fills the back of the unit. Fins or channels in concentric circles around the bulb cut side spill. The resulting beam is a straight, almost parallel column of light, similar to that of a xenon unit but not as sharp. Unlike a xenon lamp, however, tungsten BPs can be put on a dimmer. A flood/spot knob widens or concentrates the beam slightly (5-15°) by sliding the lamp base relative to the mirror.

BPs are all about showing shafts of light in atmosphere. Diffusion fog, special effects smoke, or dust in the air gives the shafts shape. The field of a BP is slightly uneven. If you point the light at the wall, you can almost make out the magnified image of the lamp filament projected on the wall by the mirror reflector.

AREA LIGHTS AND BACKING LIGHTS

Chicken coops and space lights

Chicken coops and space lights are commonly hung overhead throughout a very large set to fill the space with a general soft illumination. The chicken coop (Figure 3.30A) hangs on a chain and uses six 1000 W silver bowl globes. The globes are silvered on the bottom to prevent direct hard light from shining downward.

A spacelight (Figure 3.30B) consists essentially of six 1k nook lights configured like spokes of a wagon wheel, pointing down into a silk cylinder. At the bottom is a round diffusion ring to which a diffusion material or gel can be clipped. Spacelights are available in 1k, 2k, 6k, and 12k versions. Most can be ordered with Socapex input. Thus, the lights are individually controlled either on a dimmer or by individual on/off switches at the distribution point (Chapter 14 explains more about Socapex and switch boxes).

"Super" or "Maxi" versions of coop lights and spacelights are redesigned to use PAR lamps in place of the original lamps. Super Coop (Dadco), Maxi Coop and Maxi Spacelite (Mole-Richardson), Top Light (Finnlight), and Mac Tech 6 and Mac Tech Spacelight (B&M) are examples of overhead

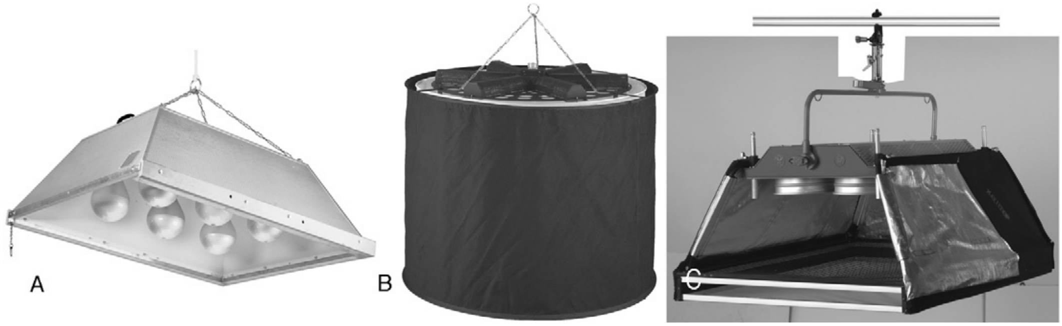

FIGURE 3.30

Coops (A) and spacelights (B) are available with either a single 60 A connector or Socapex connector, which allows individual control of all six lamps. Spacelights are available in a 2k version (two 1k lamps), a 6k version (six 1k lamps), and a 12k version (six 2k lamps). (C) The Super Coop employs six 1000W PAR 64 lamps, and two diffusion layers to create a very strong down-light.

(Courtesy Mole-Richardson Company, Los Angeles, CA.)

lights employing PAR optics to increase the downward light output within a diffused source (Figure 3.30C). These lights are four or five times brighter directly below the fixture than a normal spacelight of the same wattage. The lights are brighter because they act less like a lantern and more like a directional source.

Scoop lights and skypans

Scoops and skypans (Figure 3.31) are very simple lights. They consist of an exposed bulb mounted in a large white reflector. Scoops are 1 or 2k; skypans can be 2k, 5k, 10k, or 20k.

Skypans are used for lighting scenic paintings, backdrops, or backings evenly from side to side and top to bottom. The light can be made softer and more even by employing a frame of diffusion. The gel frame fits into a metal skirt that one attaches to the face of the light.

Cyc strips, ground rows, and borders

A *cyc strip* is a row of open-face lights having an asymetrically-shaped reflector that concentrates the light where the beam has a longer throw in order to illuminate a vertical surface from the top and/or bottom, evenly. The term *cyclorama* (or cyc) refers to a seamless wall used as a backdrop. The term is borrowed from theater where a seamless canvas, muslin, or scrim material is commonly used behind the sets, often to create a skyline, and lit with cyc strips. In film and television we commonly use an infinite cyc – a permanent hard wall built with a curve at the bottom that seamlessly transitions into the floor so there is no visible line at the base of the wall. A white cyc is commonly used to create a "limbo" set. It may also be painted blue or green for shooting foreground elements for matte photography.

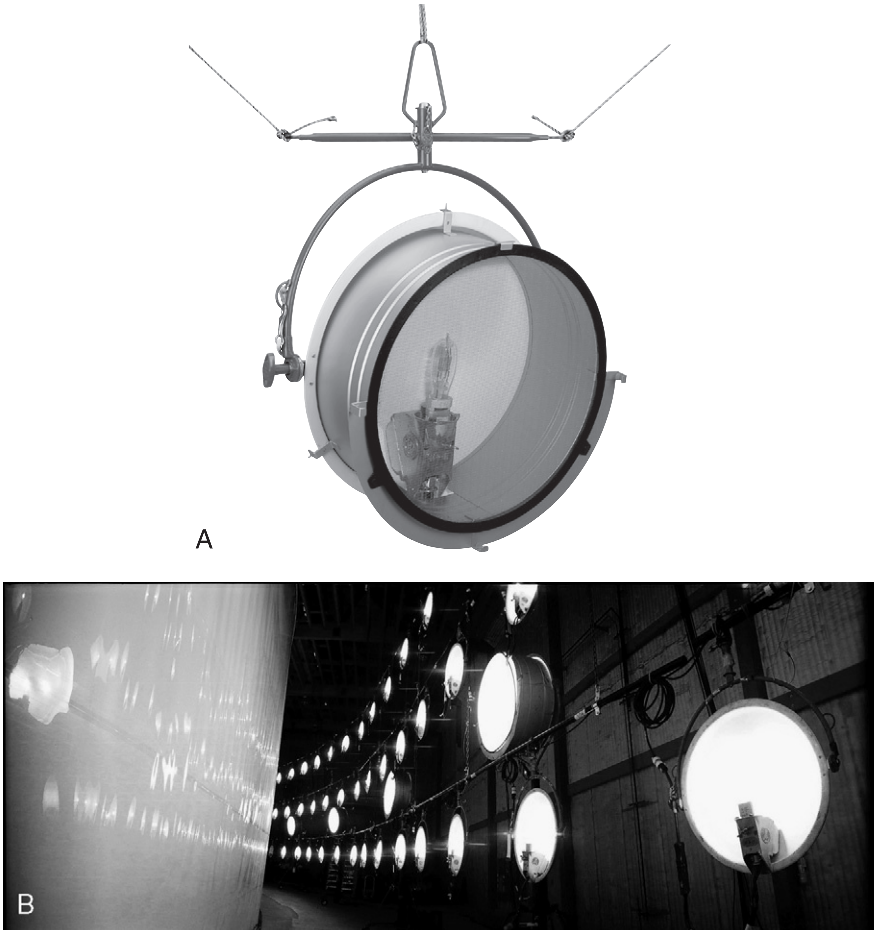

FIGURE 3.31

A 5k skypan hung on a trapeze. (Courtesy Mole-Richardson Company, Los Angeles, CA.) (B) Skypans backlight a translight back drop. (Photo by Mike Bauman.)

Cyc strips come in either short strips of 1, 2, 3, or 4 lights or longer strips of 6, 8, 9, or 12. The larger strips are wired in groups to provide three or four separate circuits for different colored gels, with one circuit of several lights per color (Figure 3.32).

A four-circuit *cyc* strip might have the three primary colors of light—red, green, and blue—plus either a white circuit or a second blue circuit. (Blue gel absorbs more light than the other colors and is therefore weaker.) By mixing the primary (or other) colors using dimmers on each circuit, the *cyc* can be made any color or can take on a gradation of colors from top to bottom—simulating a sunrise, for example.

Cyc strips may be positioned on the floor, called a *ground row*, or in a trench below floor level (sometimes built into theaters), pointing up at the *cyc*; they may also be hung from pipes or battens in

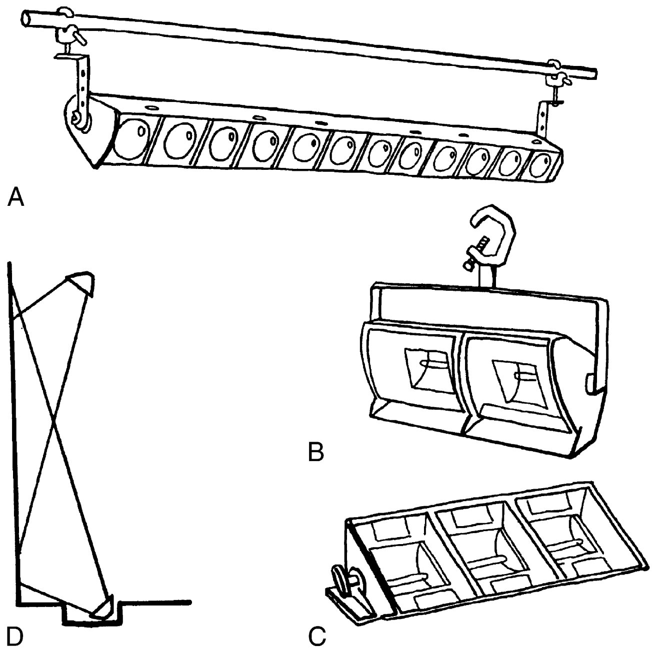

FIGURE 3.32

Cyc lighting: (A) a border light; (B) a two-light far *cyc* (also made in strips of many lights and in groups of four); (C) a ground-row *cyc* strip (comes in strips of 1, 2, 3, 4, 6, 8, 9, and 12 or more lights); (D) the typical *cyc* lighting method, which lights the *cyc* evenly from top to bottom.

front of or behind the *cyc*, pointing down at it. The angle of the strip and its distance from the *cyc* is critical for achieving even lighting from top to bottom.

Strips of PAR lights, called *border lights* (Figure 3.32A), are also used to light *cycs* and curtains. PARs have a better throw and a tighter, more intense beam, which is sometimes needed on a very tall *cyc* to carry light into the center of the cloth.

SMALL FIXTURES

Screw-base fixtures

The Lowel K5, Desisti Pinza, and similar fixtures provide a regular screw socket that can be fitted with a photoflood (or any other type of medium screw-base bulb) of up to 500 W. Because K5 kits are lightweight and can be easily hung, clamped, dangled, or taped to walls and ceilings, they are easy to rig. Fitted with R-40 mushroom floods and hoods (Figure 3.33), they can create nice pools of light from above.

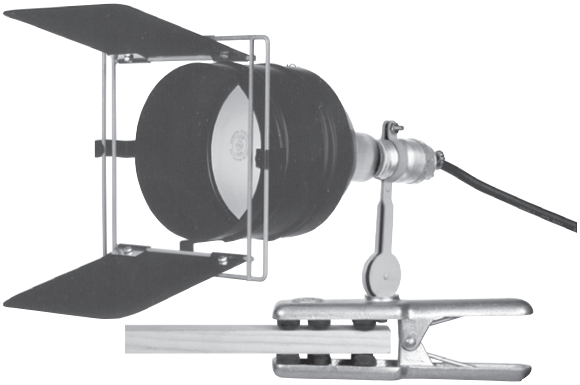

FIGURE 3.33

Molite, an R-40 bulb with attachable barn doors.

(Courtesy Mole-Richardson Company).

MR16 lamps and accessories

An MR16 looks like a small PAR lamp, two inches in diameter, and makes an excellent accent light. The MR type reflector (multi-faceted reflector) creates a punchy little beam of light, ideal for art and display lighting. MR16 lamps that have a dichroic reflector coating pull heat out the back of the light, making the beam comfortable and safe for art work. They come in a variety of beam widths including 8°, 24°, and 36° and wattages from 20 W to 100W, as well as a selection of color temperatures. Lee Filters makes a range of accessories to fit MR16 lamps, including louvers, gel holders, clip-on baffles and barn doors, and a variety of different diffusion lenses that spread the beam and soften the edges (Figure 3.34). Bi-pin MR16 light fixtures use several different pin spacings for lamp pins and sockets. GU10, GU8 and GU7.9 are used on both 120V and 12V fixtures. GU5.3 are typically 12V only. Make sure you match the lamps to the fixtures. The track-lighting type is 12 V, uses a transformer, and has a GX-5.3 base, shown in Figure B.1. Fortunately, 120-V versions of MR-16s are also available with a standard medium screw base in 75 and 150 W.

FIGURE 3.34

MR16 accessories: barn doors, gel holder, grids, louvers, diffusion glass (not shown).

(Courtesy Lee Filters.)

FIGURE 3.35

The stick-up illustrated is 3 in. tall, and weighs 9 oz. with its 9-ft. power cord. It takes either 100 W, 120 V, or 125 W, 12 V bulbs. It comes with a wire frame for securing gel and diffusion.

(Reproduced by permission of GAMPRODUCTS, INC., Los Angeles, CA.)

Stick-up kits

A stick-up is a very small open-face light that can be taped or clipped into the smallest of places. It can be fitted with a 100- or 200-W, 120-V bayonet-base bulb, or with a 100-W, 12-V bulb. The latter is ideal as a dome light in an automobile, because it can run off the car battery (Figure 3.35).

Because a stick-up is so small and light, it can be taped in place or hung on pushpins. When the light is placed against a surface, insulate the surface with a double or triple layer of Refracil heat-resistant cloth. You can wrap a piece of blackwrap around the back of the fixture to act as barn doors.

CHAPTER

Stands and rigging

4

Lighting technicians find themselves having to hang lights in all kinds of places, so naturally, over the years, ways have been devised to secure a light almost anywhere. People are constantly inventing and reinventing these devices. The basics are described in this chapter; check manufacturers' Web sites for the most up-to-date information (ARRI, Matthews, Norms, American, Modern Studio Equipment, Versales, The Light Source, City Theatrical and many others; see also Appendix F).

Lights are typically mounted in one of three ways. The smaller movie lights (baby 2k and smaller) have a ⅝-in receiver that can be mounted on a ⅝-in "baby" pin. Larger movie lights have 1⅛-in. pin which fits into a 1⅛-in "junior" receiver on the stand or rigging hardware. Concert and theater venue lights may be delivered with a pipe clamp bolted to the yoke. This can be removed and replaced with a baby receiver for stand-mounting if necessary. Accordingly stands and rigging hardware are identified as either "baby" or "junior".

STANDS

A wide range of light stands are available. Stands of both types come in various heights: two-riser, three-riser, and "low-boy". Stands may be made of aluminum, which is lightweight, or steel, which is stronger.

Baby stands

Figure 4.1 shows some of the standard baby light stands. The most versatile baby stand for location work is a steel three-riser stand with a mountain leg. Loosening the T-handle on the top collar and pulling up can quickly retract the legs. The legs have a wide base for stability, and the mountain leg makes it easy to level the stand when it is placed on uneven ground, on a stair, over the edge of a curb, or leaning against a set wall (Figure 4.2).

Rolling stand

Baby rolling stands are convenient when working in the studio on a level surface. Many rolling stands have brakes that snap into a locked position.

Low stands

When you need a light placed low, a mini-baby (22-50 in.) or preemie (31-70 in.) stand comes in handy. Table 4.1 lists the basement and top floor for many common stands.

Set Lighting Technician's Handbook, 4e. DOI: 10.1016/B978-0-240-81075-1.00004-0

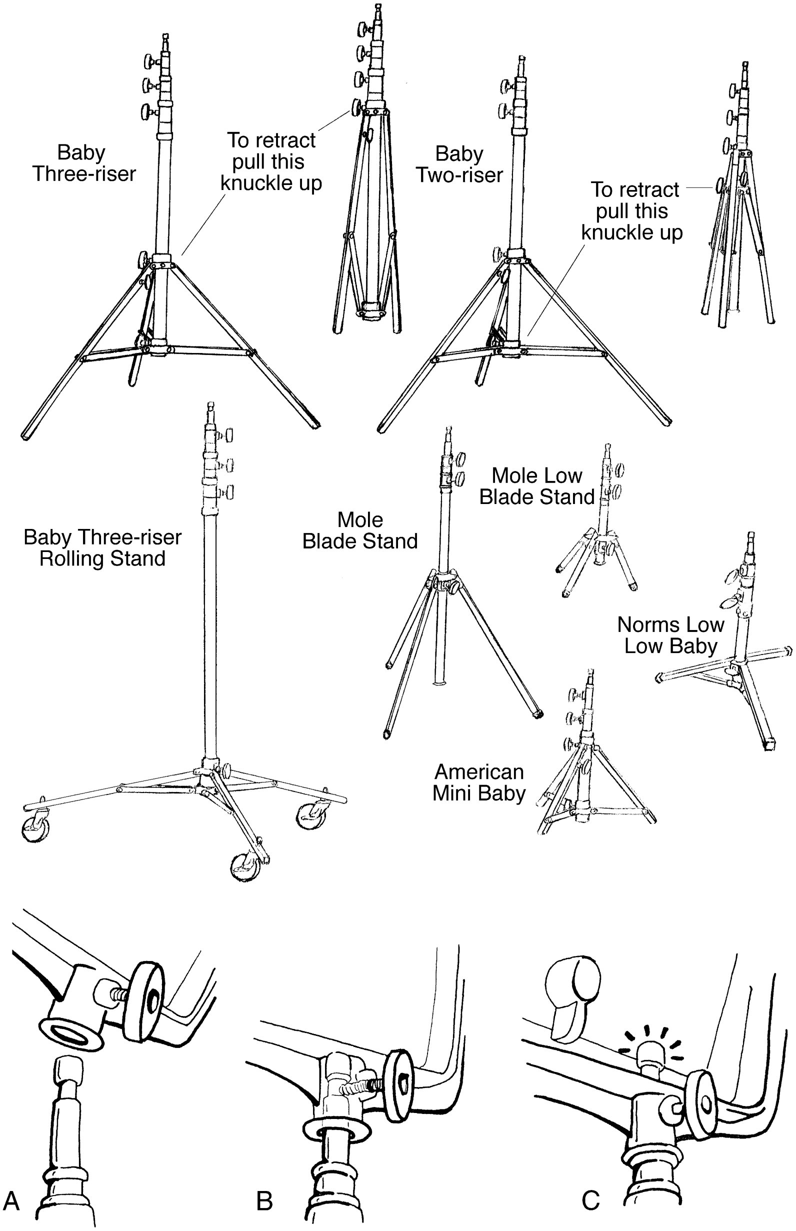

FIGURE 4.1

To retract the legs of most stands, loosen the upper tie-down knob and pull the legs up and in. With some stands, the legs retract by loosening the bottom tie-down knob and sliding that collar upward. A ⅝-in. baby pin inserts into the receptacle on a fixture (A). When mounting the light, the pin should be flush with the receptacle and not stick through. This assures that the T-handle engages the indent of the pin (B). Also, some lights (notably the baby junior) do not tilt properly if the pin sticks through (C).

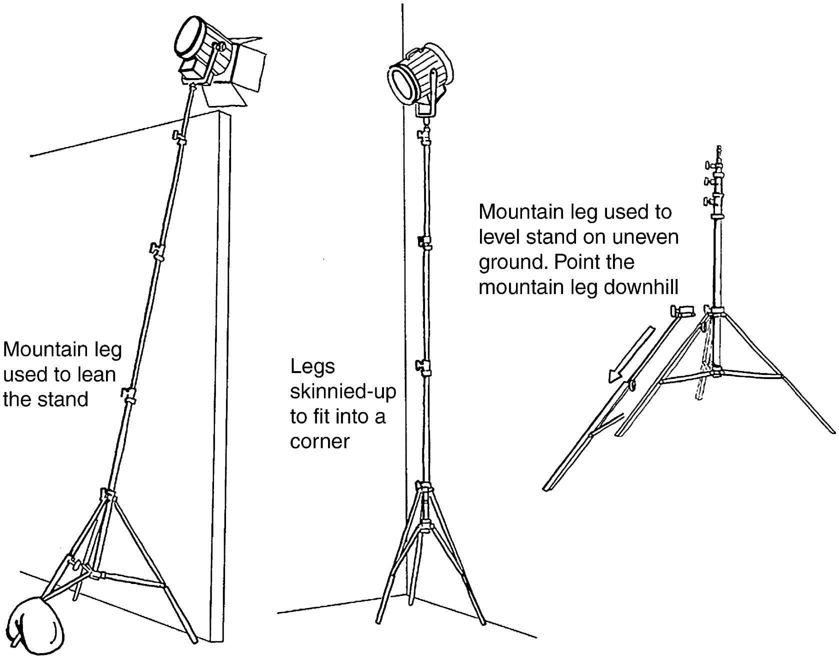

FIGURE 4.2

Alternative stand configurations.

Table 4.1 Stands

Name	Type	Risers	Minimum height	Maximum height	RM leg	Brand
Low baby stands						
Low blade stand	Al	2	15″	38⅞"		Mole
Mini-preemie	St	2	20″	39″		Matthews
Preemie baby	Al	2	31″	*5′10″*		Matthews
Mini-baby	St/Al	2	22″	*50″*	X	American
Low low baby	Al	2	20″	3′3″		Norms
Low hefty baby	Al	2	33″	5′7″		Norms
Baby stands						
Steel maxi	St	3	34″	10′		Matthews
Beefy baby standard	Al	2	37″	8′3″		Matthews
Beefy baby, 3-riser	Al	3	45″	1	X	Matthews
Baby, 2-riser	St/Al	2	40″	9′4″	X	American
Baby, 3-riser	St/Al	3	44″	12′5″	X	American

Continued

Table 4.1 Stands—cont'd

Name	Type	Risers	Minimum height	Maximum height	RM leg	Brand
Baby light, 2-riser	Al	2	44″	9′4″		Norms
Baby light, 2-riser	St	2	52″	10′6″		Norms
Hefty baby, 2-riser	Al	2	47″	9′10″	X	Norms
Hefty baby, 3-riser	Al	3	50″	12′10″	X	Norms
Low junior stands						
Runway base only		0	11″	11″		Matthews
Low boy	St	2	33″	6′9″	X	Matthews
Low boy	Al	2	37″	6′9″	X	Matthews
Low combo, 1-riser	St	1	29″	4′0″	X	American
Low combo, 2-riser	St	2	32″	5′6″	X	American
Low combo, 2-riser	St	2	33″	5′7″	X	American
Low boy		2	36″	5′8″	X	Norms
Rolling folding stand	St	1	221/4″	32″		Mole
Junior stands						
Combo	St	2	48″	11″	X	Matthews
Sky high	St	3	52″	14′	X	Matthews
Mombo combo	St	4	76″	27′	X	Matthews
Light duty combo	St	2	48″	10′5″	X	American
Heavy duty, 2-riser	St	2	50″	11′3″	X	American
Heavy duty, 3-riser	St	3	51″	14′3″	X	American
Alum combo, 2-riser	St/Al	2	48″	10′3″	X	American
Alum combo, 3-riser	St/Al	3	51″	13′9″	X	American
Mombo combo	St	4	5′8″	23′5″	X	American
Standard		2	54″	11′2″	X	Norms
Sky high		3	58″	13′	X	Norms
Sky high	Al	3	61″	13′	X	Norms

Notes: *"RM leg" stands for "Rocky Mountain leg."*
"St/Al" means the stand has steel legs and aluminum risers.

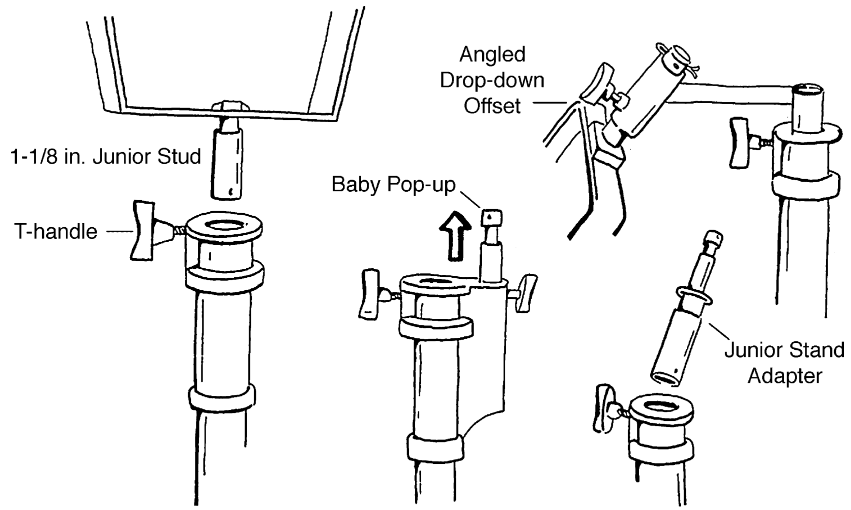

FIGURE 4.3

The 1⅛-in. junior pin fits into the receptacle on the stand. The T-handle should engage the indented part of the pin. Some stands have a baby pop-up, which allows the junior stand to support either a baby or a junior fixture. An angled drop-down offset allows a light or reflector to hang lower than the lowest height of the stand. The 45° angle holds the light away from the stand. In the absence of a baby pop-up, a junior stand adapter can be used.

Junior stands

Combo

The junior combo stand is so named because it was designed to handle both lighting units and reflector boards. Larger fixtures, Studio 2k and larger, have a 1⅛-in. junior pin. A typical two-riser combo has a maximum height of 11 ft. A three-riser combo has a maximum height of 14 ft. Figure 4.3 illustrates the junior stand and some common stand accessories: the baby pop-up pin, the angled drop-down offset, and the baby pin adapter.

Low boy

The minimum height of a typical combo stand is 48 in. If the light must be lower than that, you need a low-boy junior stand, which has a minimum height of around 33 in. If you need to mount a light lower than 33 in., you have to under-hang the light from an offset or use a turtle stand or T-bone.

T-bones and turtle stands

A T-bone is simply a metal T fitted with a junior receiver (Figure 4.4). A T-bone can be nailed or screwed into place. It sits flat on the floor, providing a low position for larger lights. A turtle stand is nothing more than three legs joined in the center to a junior receiver. Matthews's C+ stand has removable legs, which serve as a turtle stand. The riser section of the C+ stand can be used as a stand extension. Matthews and other manufacturers also make wheeled turtle stands. Matthews calls theirs a *runway stand*.

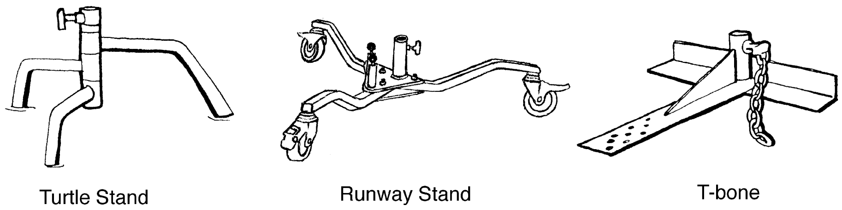

FIGURE 4.4

Three ways to place a light near the ground. A T-bone can be nailed or screwed into place in green beds or on parallels.

Mombo combo

A mombo combo is a very substantial four-riser steel stand with a very wide base (no wheels), which allows a maximum height of more than 26 ft.

Offsets, side arms, extensions, and right angles

Offsets

Figure 4.5 shows various types of baby offsets that can be used to locate the head out from the stand. They are useful when some obstruction, such as furniture or a set piece, prevents the stand from being placed under the light. Note that an offset or side arm puts the stand off its center of balance. Use sandbags on the legs as counterweights.

Risers

Risers come in many sizes; typical sizes are 6, 12, 18, and 24 in. A riser is a handy piece of hardware when a light mounted to a plate or clamp is not quite high enough. A 36-in. junior stand extension essentially adds an additional riser to a stand. It can also be inserted into the receiver on the dolly or the crane when a light is to ride with the camera.

Using stands

- See Chapter 2 for the checkout procedure for stands.
- Remember: "Righty tighty, lefty loosey." The T-handle tightens when turned to the right (clockwise) and loosens when turned to the left.
- Extend the top riser first. If you extend the second riser first, you will raise the first riser out of your reach and look like a bonehead. However, if the light is heavy for the stand, you can add strength to the stand by not using the first riser or using only part of it.
- Bag any raised stand. A good rule of thumb is one sandbag per riser. If the light were extended all the way up on a three-riser stand, you would use three bags. Place the sandbags on the legs so that the weight rests on the stand, not on the floor.
- Get help when needed. As a rule, use two people to head up any light 10k or larger. Depending on the height of the stand and the awkwardness of its position, heading up an 18k or Dino can require three or four people. Don't hesitate to round up the other electricians and grips when you need them. A heavy light can get away from you and cause injury and damage. Lifting equipment is not a contest; the lighting crew works as a team.

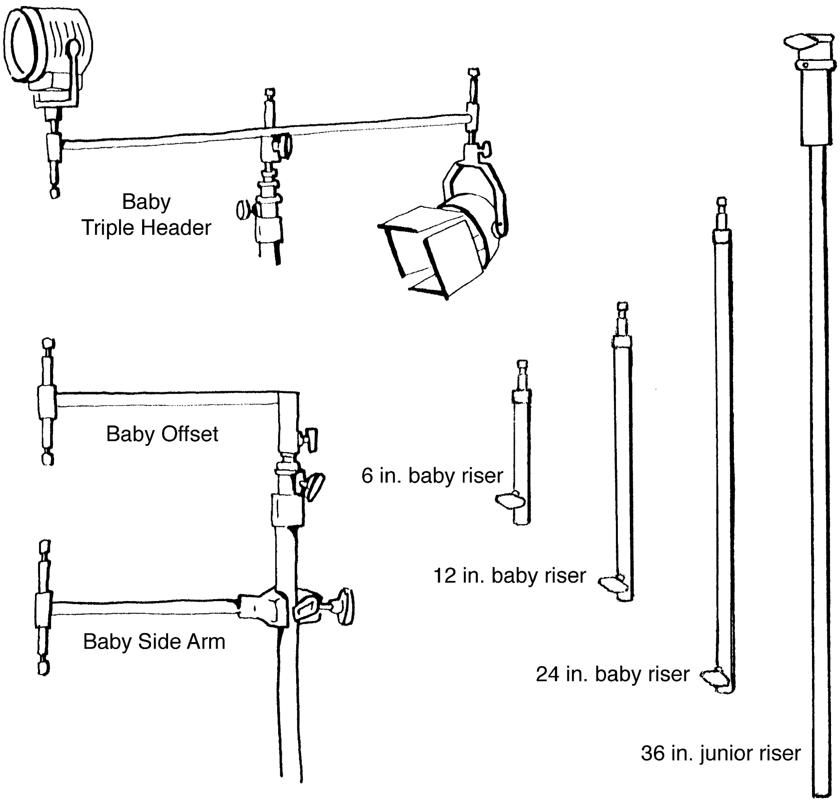

FIGURE 4.5

Offsets, side arms, double headers, and triple headers are available in baby and junior sizes.

Crank-up and motorized stands

Crank-up stands provide a mechanical advantage needed for raising heavy lights. Table 4.2 gives the weights and weight capacities of crank-up and motorized stands. They have a chain-, cable-, or screw-driven telescoping extension system with a crank and clutch so that the crank does not reverse and spin out of control under weight. Do not crank up a stand without some kind of weight on it, as this can cause problems in the inner mechanisms. The Avenger stands have a number of notable features, including a very safe gear system (Figure 4.6).

The Cine-Vator, Molevator, and similar motorized stands power the telescoping mechanism with an electrical motor that is operated by a single up/down toggle switch (Figure 4.7).

- When rolling a large light on a crank stand or motorized stand, push the stand from the back with the swivel locks *unlocked* on the two rear tires and the front tire *locked*. Steer by pushing the back wheels left or right. This way you are less likely to catch it in a rut and tip over the whole stand.

Table 4.2 Weight Capacities of Crank-up and Motorized Stands

	Floor	Ceiling	Capacity	Type
American				
Roadrunner 220	4′2″	11′3″	220 lb. (100 kg)	Crank
Big Fresnel Lamp Stand (BFL)	4′2″	12′6″	300 lb. (136 kg)	Motor
Avenger				
Long John Silver Junior, 3-riser	4′0″	11′0″	265 lb.	Crank
Long John Silver, 4-riser	5′9″	18′8″	264 lb.	Crank
ARRI				
Baby 2-section Supercrank	3′2″ (97 cm)	5′5″ (165 cm)	220 lb. (100 kg)	Crank
Short-base 3-section Supercrank	4′8″ (153 cm)	11′3″ (345 cm)	154 lb. (70 kg)	Crank
2-section Supercrank	4′10″ (147 cm)	7′7″ (232 cm)	198 lb. (90 kg)	Crank
3-section Supercrank	5′5″ (165 cm)	11′5″ (348 cm)	176 lb. (80 kg)	Crank
4-section Supercrank	5′11″ (182 cm)	15′7″ (477 cm)	154 lb. (70 kg)	Crank
5-section Supercrank	7′9″ (237 cm)	20′4″ (620 cm)	154 lb. (70 kg)	Crank
Matthews				
Lite Lift	4′1″	8′6″	85 lb. (38 kg)	Crank
Crank-O-Vator	4′11″	12′	150 lb. (68 kg)	Crank
Low Boy Crank-O-Vator	3′2″	5′5″	150 lb. (68 kg)	Crank
Super Crank	5′9″	12′6″	200 lb. (90 kg)	Crank
Cine-Vator	4′6″	12′	300 lb. (136 kg)	Motor
Mole-Richardson				
Folding Crank-up Litewate Stand	4′5″	10′	—	Crank
Molevator	5′1″	11′1″	250 lb. (113 kg)	Motor

- When the stand is in place, prevent the stand from rolling by swiveling each wheel straight out from the stand and locking each swivel. Additionally, wedges in the tires and cup blocks under the tires prevent them from turning (grip department).
- Before raising the stand, make sure it is totally leveled with cup blocks, wedges, and apple boxes, if necessary (grip department).
- Use your strong arm to turn the crank to raise and lower the light. Never release the clutch without having a good grip on the crank. A properly adjusted crank should not spin when the clutch is released. However, they often do. If the crank gets away from you, there is a good chance you will not be able to get hold of it again before the lamp hits you in the head. There is also a good chance you'll hurt yourself trying to grab hold of the spinning crank. If you lose control, let go of the clutch and get out of the way of the light.

FIGURE 4.6

Avenger Long John Silver (shown here) and Long John Silver Junior (by Avenger Lighting) are high-capacity crank stands with some unique features. The Junior version has a loading height of 48 in., significantly lower than most crank stands, making it much easier and safer to head up big heavy lights. The taller version of the Avenger is a four-riser light stand with a maximum height of almost 18 ft., 7 in., making it the tallest of its type. The avenger stands feature leg pistons that help in folding and unfolding the stand, which is quite heavy. Unlike other crank stands, it has a leveling leg. The winch-type crank provides two crank handles, so the user employs both hands to crank. The gear box is designed so that all the risers work simultaneously and has a manual safety block, as well as an internal one, and internal friction, which greatly reduces the danger of the crank getting away. The wheels also have very good brakes and the wheel swivels lock in a variety of positions.

(Photo by Damon Liebowitz.)

Grip stands

For the most part, the grip stands are used for flying overhead sets and setting flags, nets, diffusion frames, and so on. However, in special situations, they are needed as light stands.

C-stands

Q: How do you drive an electrician crazy?
A: Lock him in a small room with a C-stand.

The Century stand, or *C-stand*, is a versatile, all-purpose rigging gadget that is the centerpiece of the grip's equipment. Its components are like the parts of an erector set, and setting C-stands is a little-

FIGURE 4.7

A Cine-Vator stand. These stands can handle the heaviest lights made (up to 300 lb.). The motor is usually 115 V AC (at about 6 A) but can be 115 V DC, 220 V AC, or 220 V DC.

(Courtesy Matthews Studio Equipment, Burbank, CA.)

appreciated art form. Given enough time and enough C-stands, a grip could build a scale model of the Eiffel Tower. Grips normally use the stands for setting flags, nets and diffusion, but they are also very handy for electricians for rigging small lights, like fluorescents, especially when the light needs to be cantilevered out on an arm (Figures 4.8 and 4.9).

Knowing the proper technique will save you much embarrassment; grips like nothing better than to heckle an electrician who is making a mess of a job with a C-stand:

- Place the longest leg under the extended arm. This helps stabilize the stand. Always sandbag the legs when putting weight on an extended arm (Figure 4.8).
- Work with gravity, not against it. When you are standing behind the stand with the arm pointing away from you, the knuckles should be on your right. In this way, when weight is put on the arm, gravity pulls the grip head clockwise, which tightens it. If the knuckle is on the left, the weight will eventually loosen the knuckle, and the whole rig will collapse (very bad form).
- Avoid configurations in which the back end of the arm sticks out, especially at eye level; it could hurt someone. There is almost always an alternative configuration that eliminates the hazard. If it's unavoidable, place a tennis ball or Styrofoam cup on the end of the arm so people will see it.

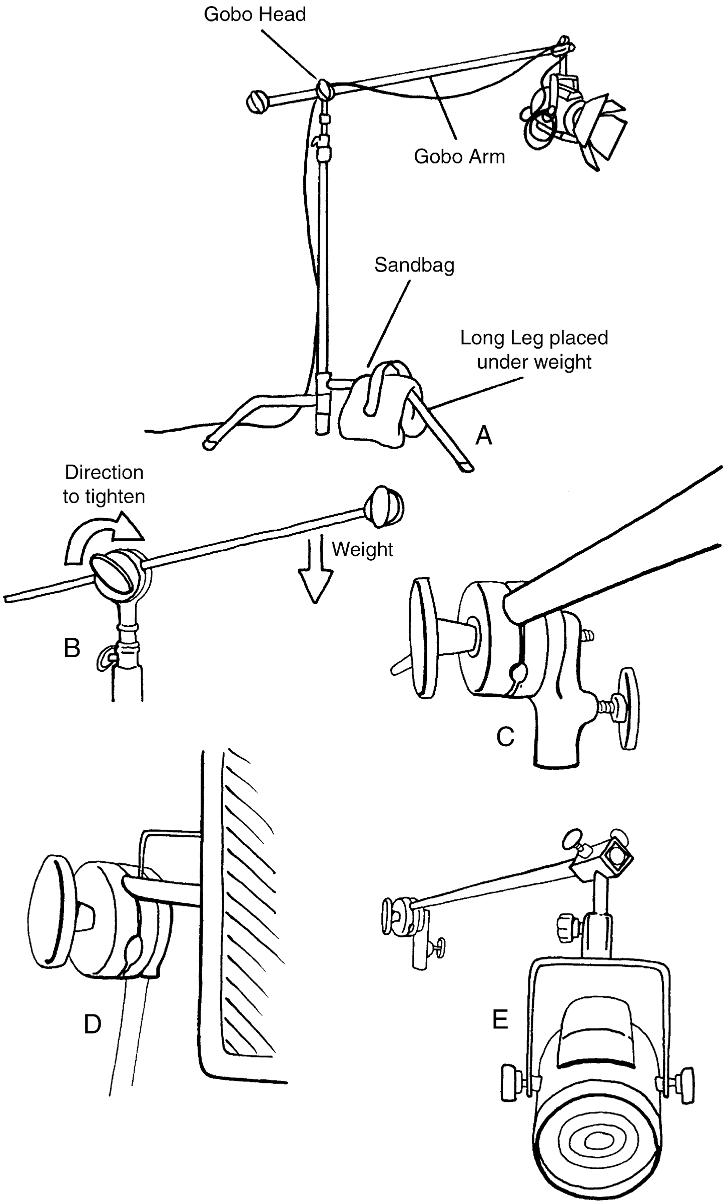

FIGURE 4.8

(A) C-stand supporting a light fixture. (B) Orient the knuckle so that gravity tightens it ("righty tighty"). (C, D) The grip head accepts various sizes: a ⅝-in. hole for the gobo arm or a baby pin, and a ⅜-, ½-, or ¼-in. hole for nets and flags. (E) The light fixture shown uses a bar clamp adaptor (used on furniture clamps) to attach to the gobo arm.

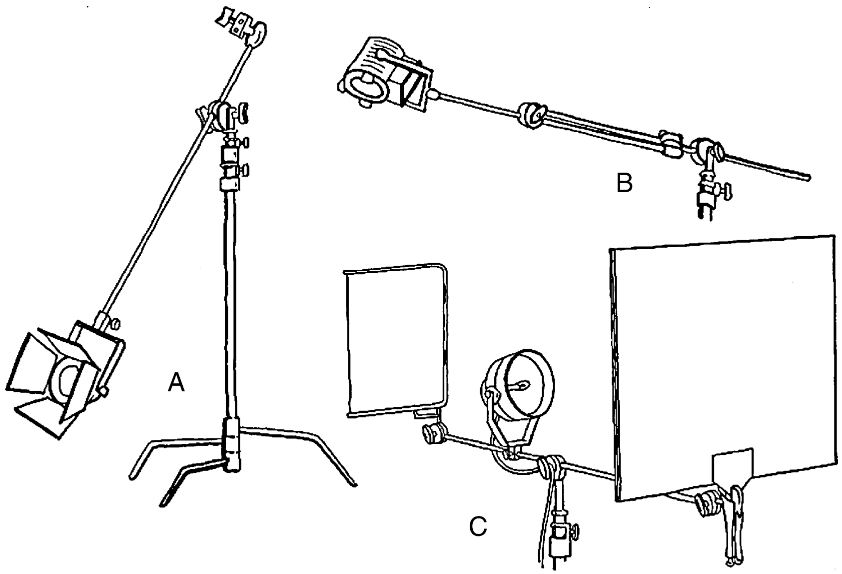

FIGURE 4.9

Some special uses for C-stands: (A) to place the light in a low position; (B) to arm the light out over the action (here, two gobo arms coupled together); (C) to work with a bounce card rig like this, which uses a single stand to support the light, bounce card, and a net.

- Place the sandbag on the top leg so that the weight is on the leg and not resting on the ground.
- Always place the C-stand on the "off-camera side" of the light—the outside, as viewed from the camera. This helps keep grip equipment out of the movie.

Medium, Hi, and Hi-Hi rollers

A medium roller stand is slightly taller than a junior combo, about 14 ft. maximum, and has wheels, which makes it easy to move around. The wheels have brakes that should be locked once the stand is placed. In addition to a junior receiver, roller stands typically provide a 4-in. grip head for mounting overhead frames, large flags, and other grip gear. A hi-hi roller is especially useful when height is required; it has a maximum height of 20 ft.

Booms

Boom poles allow a fixture to be cantilevered over or behind the actors in places where it could not be mounted by other means. These are best used for lightweight fixtures such as hanging a lantern light between two actors. Booms vary in size and strength. The small ones mount on a baby stand and provide about a 4-ft. arm with almost as much counterweight length. The larger ones mount on a junior stand, have more length and more counterweight, and provide either a junior or a baby mount for the light. Sandbags can be added for additional counterweight.

Stand maintenance

Modern stands are made of stainless steel and aluminum. Stainless steel stands are extremely weather-resistant. A well-made stand will not rust or corrode. When stands get muddy, they should be cleaned so that dirt does not get inside, between the risers. Wipe each riser down with a rag or towel. If a riser starts to bind, lubricate it with silicone spray.

Occasionally, the Allen screws that secure the bonnet castings and the riser castings to the tube parts of a stand get loose and the castings come off. It is a simple matter to push the castings back into place and tighten down the Allen screws. Be sure to keep the castings tight. If the casting comes off while you are raising a light, the riser will separate from the stand and you'll wind up balancing the light on the riser like an acrobat with teacups (except that a 4k par costs a little more than a tea cup when it shatters on the ground).

RIGGING HARDWARE

Baby and junior nail-on plates

A nail-on plate, also called a wall plate or pigeon plate (Figure 4.10), mounts to a surface with screws. Use a cordless electric drill with a Phillips bit and wood or drywall screws. The plate can be mounted to a horizontal surface, a wall, or a ceiling, but be sure that you are screwing into something solid. If you are screwing into a set wall (usually ¼-in. plywood), place a piece of cribbing on the other side of the wall to give the screws something to hold to.

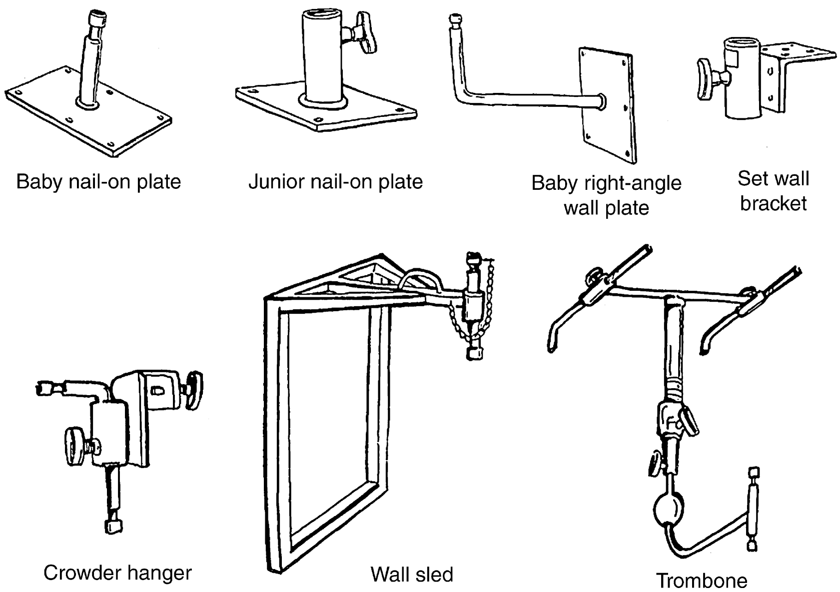

FIGURE 4.10

Plates and hangers for set walls.

The grips usually prepare several apple boxes with nail-on plates. When mounted on an apple box, a nail-on plate provides a stable lighting position that is handy for setting a light on the floor or on a counter top.

Set wall mounts

Figure 4.10 shows a variety of set wall mounts.

Set wall bracket

A set wall bracket is a right-angle plate that mounts to any right-angle corner, such as the top of a flat.

Crowder hanger

A crowder hanger fits over the top of a door or on 2 × 4 lumber. It can be used with a baby adapter that provides two mounting positions—one above and one below the hanger.

Edge plate bracket

An edge plate bracket is similar to a crowder hanger. It is used to mount lights to the side edge of a green bed (explained shortly).

Wall sled

A wall sled is suspended on rope from the top of a set wall. The weight of the light holds the sled in position against the wall without screws or tape. Wall sleds are available with either a junior or a baby mount.

Trombone

Like the crowder hanger, a trombone also fits over the top of the set, but it is adjustable to any width of wall. It provides an adjustable drop-down position for the light. Use a rubber ball on the telescoping arm to prevent it from scraping the wall. A trombone can have either a junior or a baby mount.

Clamps

C-clamp

C-clamps (Figure 4.11) come in various sizes: 4, 6, 8, and 12 in. Each one has two baby pins or a 1⅛-in. junior receiver welded to it.

With any of the clamps shown, to prevent puncturing or marring the beam and to increase the surface area of the clamp, insert two pieces of 1×3 cribbing between the clamp and the surface. Wrap the cribbing in duvetyn cloth when it is important not to scratch the finish.

A common problem when mounting lights to a C-clamp on top of the set wall is that the light cannot be tilted down far enough. Use the angled pin on a C-clamp to get around this problem.

Furniture clamp and bar clamp

Furniture clamps and bar clamps are normally used by woodworkers to clamp work pieces together during glue-up. Furniture clamps come in various sizes (6, 12, 18, 24, and 36 in.); standard bar clamps are 48 in. (but can be any length), all of which are adjustable. Furniture clamps are typically

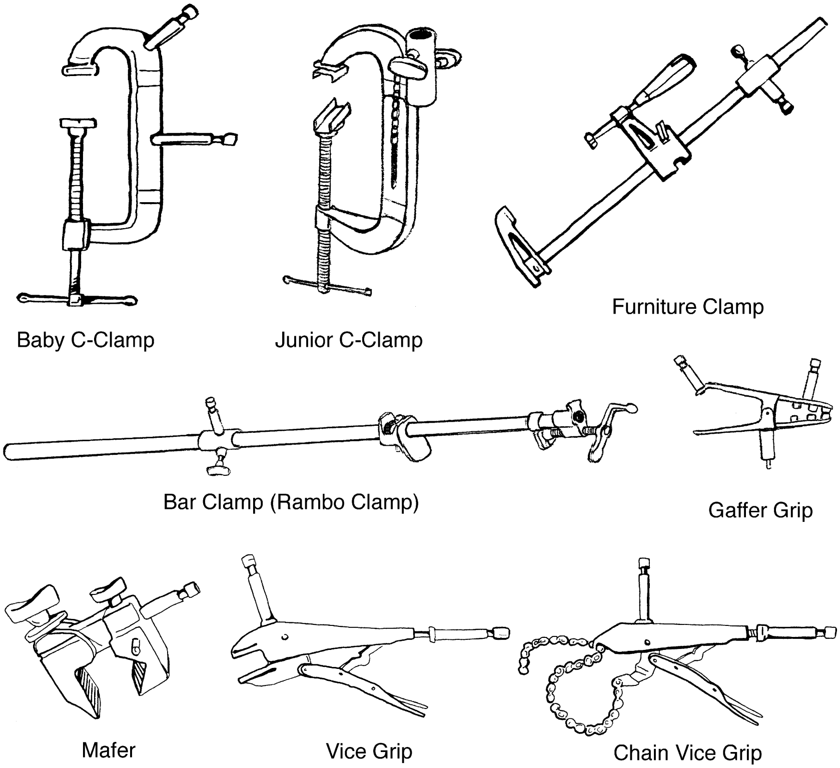

FIGURE 4.11

Clamps.

used to undersling lights from ceiling beams or square pillars that are too wide for a C-clamp. As with C-clamps, use cribbing to increase the surface area of the clamp and to protect the surface to which you attach the clamp.

Gaffer grip

A gaffer, or gator, grip is a spring clamp with rubber teeth. It is used to mount smaller lights to doors, pipes, and furniture.

Mafer

A mafer (pronounced *may-fer*) is a versatile mount, small but strong. A cammed screw mechanism closes and opens the rubber-lined jaws. It can attach to any round surface from ⅝ to 2 in. in diameter and any flat surface from $\frac{1}{16}$ to 1 in. thick. The baby pin snaps into place with a spring-loaded lock. The removable pin can be exchanged for accessories, such as a flex arm, a double-header offset arm, or a right-angle baby pin.

Vice grip

The adjustable width of a vice grip provides a strong grip. As with any vice grip, the clamp is released by pressing the unlocking handle.

Chain vice grips and "Candlesticks"

Figure 4.12 shows a correctly threaded chain vice grip. A chain vice grip provides a very solid mount to any pipe up to 6 in. in diameter. It is used to mount a light to a standing pipe or pillar. Using a chain vice grip is preferable to using a clamp in this application, because a clamp can crush a pipe; a chain vice grip, on the other hand, applies force evenly around the diameter of the pipe. Chain vice grips are often used to secure a "candlestick" to a standing post. A candlestick is nothing more than a heavy metal tube, one end of which is sized to receive a junior pin. It is like a junior riser, but is stronger, because it does not have a cast aluminum receiver. (When heavy lights are rigged to an aerial lift, for example, a great deal of sideways force may be exerted on the receiver when the aerial lift stops and starts. A normal junior receiver casting can crack open under such stresses.) To make sure that the vice grip does not open, always wrap tape around the handle after the chain vice grip is in place.

People are sometimes tempted to mount small lights to plumbing pipe on location. This is a bad idea. Although it may look sturdy, old cast iron pipes can be paper-thin, corroded on the inside after years of use. *Never* mount lights to fire sprinkler system pipes. It is against fire codes and a bad idea. If you rupture the pipe, it can flood the building.

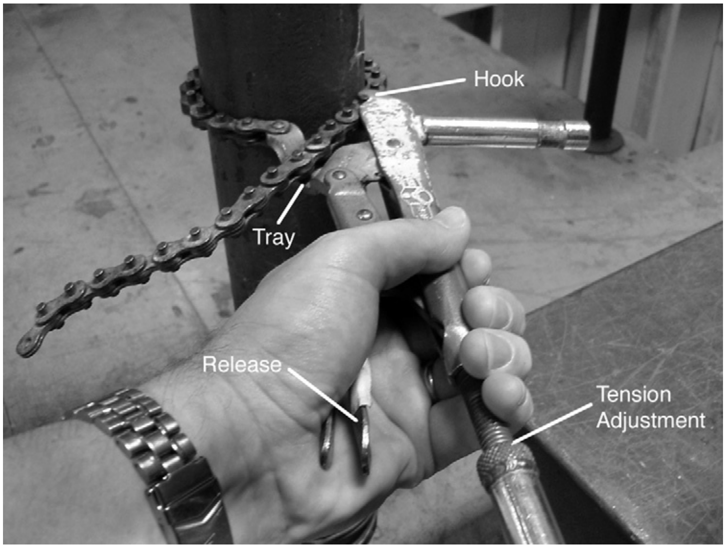

FIGURE 4.12

Face the tray up, toward you. Wrap the chain around the post and into the tray. Engage the chain's pins into hooks and squeeze the vice handles until they snap closed. To loosen or tighten the tension, turn the knurled knob before closing. Wrap tape around the handles to ensure that the vice does not open if it gets accidentally bumped. To release, remove the tape and pull the release lever.

Grids and green beds

Pipe clamp

Pipe clamps (Figure 4.13) are used when hanging lights from an overhead pipe, grid, or truss. Pipe clamps come with a safety pin attached to the clamp with a safety chain. The cotter pin prevents the receiver from slipping off the pin. Always use the safety pins when hanging lights.

Grid clamps, couplers, and claws

A grid clamp is another clamp used for attaching lights to pipe, but it has a much more secure grip on the pipe, and encircles the pipe with equal pressure, rather than pinching the pipe as a pipe clamp does. There are various types of couplers and clamps of this type, which are used to secure pipe to other pipe, or to secure lights of various kinds to pipe. Moving lights often employ two coupler clamps, because the torque of the moving fixture requires a very firm attachment. Figure 4.14 shows several examples of couplers clamps that are used to secure lights. In addition to having a much better grip on the pipe than a pipe clamp, grid clamps, couplers, and claws also take up less room than a pipe clamp.

Telescoping stirrup hanger

To get a light lower than the height of the grid, use a telescoping hanger to lower it to the desired height. Hangers have a stirrup to which you attach a pipe clamp. They are also made with a baby pin or junior receiver instead of a stirrup.

Greens and bazookas

In most studio sound stages, wooden catwalks called green beds or greens or decks are suspended above the set to provide lighting positions. Along the edge of the greens, at 18-in. intervals, are holes onto which a junior pin fits. A light may be inserted directly into this receiver or a bazooka can be inserted into the hole. A bazooka is like a one-riser stand with no legs. An L-shaped bracket fits over the catwalk's hand rail to support it.

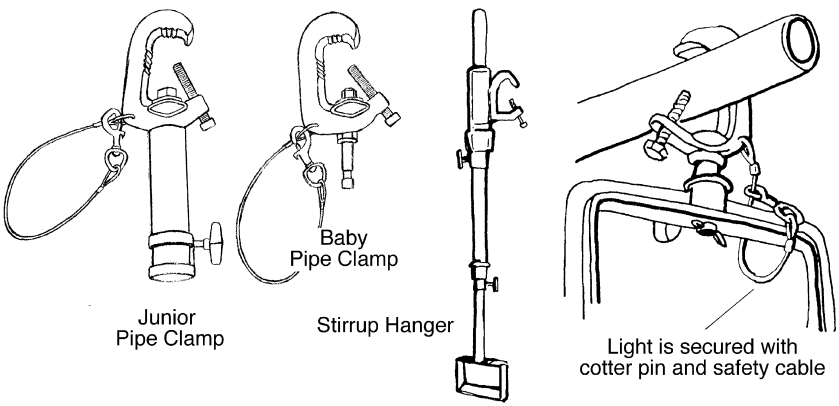

FIGURE 4.13

Pipe clamps.

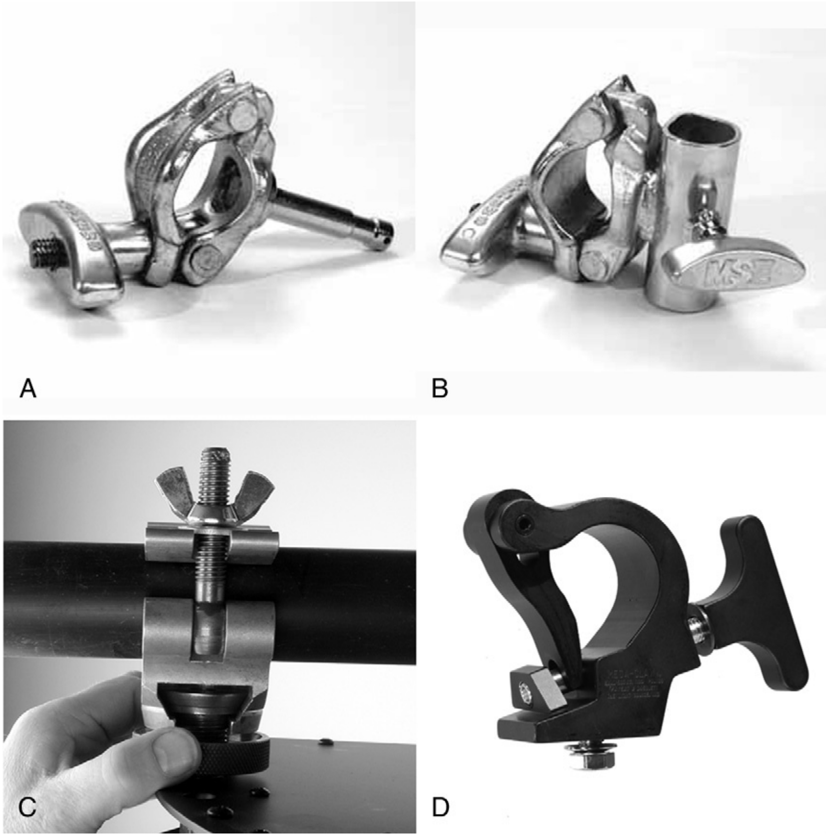

FIGURE 4.14

Grid clamps provide a very secure grip to the pipe for lights with either a baby receiver (A), or junior pin (B). (A) baby grid clamp; (B) junior grid clamp (courtesy Matthews Studio Equipment). Unlike a pipe clamp, a grid clamp does not allow you to rest the weight of the light on the pipe while tightening the clamp. You have to attach the clamp first, and then hang the fixture. With moving lights, the couplers are bolted to the light, so hanging these heavy lights with traditional couplers is a pain. Couplers such as (C) the T-slot coupler (courtesy City Theatrical, Inc.) or (D) the Mega Claw (courtesy The Light Source, Inc.) allow the weight of the fixture to rest on the pipe while the coupler is locked in place.

Other rigging hardware

Wall spreader and tube stretcher

Wall spreaders (Figure 4.15) support lights by exerting pressure against two opposite walls or the floor and ceiling. A 2-in. × 4-in. or 2-in. × 6-in. piece of lumber creates the span. The hardware mounts to either end of the lumber and uses a threaded post to apply pressure against the walls. Lumber must be cut to fit the particular span needed. A wall spreader is handy as a means for mounting overhead lighting or grip equipment when shooting on location in a relatively small room or corridor.

A wall spreader can create a secure overhead beam of up to about 16 ft., from which lighting fixtures can be hung. With a long span, be sure that the hardware is aligned with wall studs and screw the wall spreaders to the wall. A *tube stretcher* essentially adapts a wall spreader for use with speed-rail pipe instead of lumber.

Matth pole

A Matth pole, or pole cat, is a smaller, lighter-duty version of a wall spreader, especially useful in doorways or narrow halls or used vertically between floor and ceiling. A Matth pole can support lightweight fixtures or grip equipment.

Suction grip

Suction grips of 4 or 6 in. can be used to affix small lighting units to nonporous surfaces, such as a window or car hood. These grips generally use a cam to create the suction; they are not as strong as the larger, pump-type grips. Suction grips come with baby pins only and should be limited to use with smaller lights.

Scissor clip

A scissor clip is used to mount small lightweight lights to the metal frame of a dropped ceiling. The scissor closes over the metal strips that support the ceiling tile. It is tightened in place by turning the ⅝-in. pin. Cables can be dressed above the ceiling or clipped to the metal strips with small grip clips.

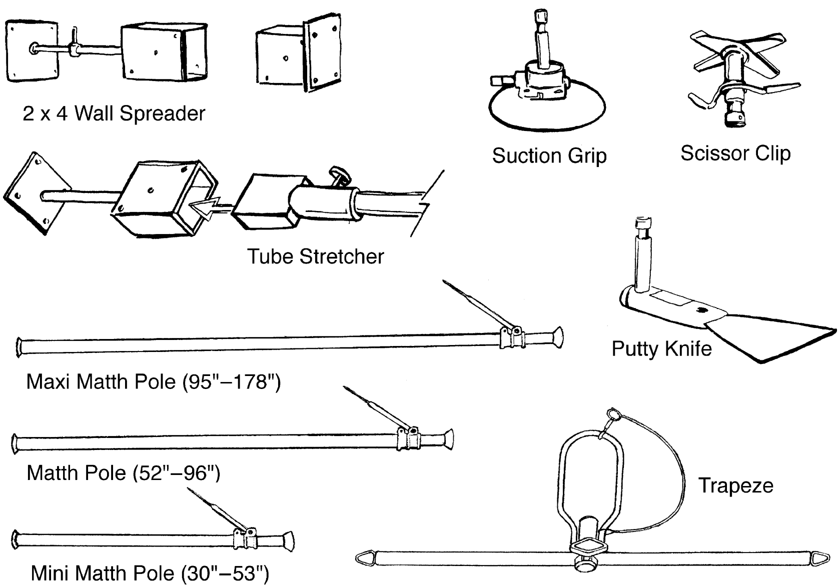

FIGURE 4.15

Rigging equipment.

Putty knife
A putty knife can be wedged in a windowsill or door frame. It provides a baby pin for a small light fixture.

Trapeze
A trapeze is used to dead-hang a light of any size from a rope. It provides a junior receiver. Eyelets at each end of the trapeze are provided for guy wires, which aim the light and hold it in place once in position.

CHAPTER

Lighting objectives and methods

5

Let's put hardware aside for the moment and discuss the bigger question of what we want to accomplish with lighting and how we go about it. What considerations do the director of photography and gaffer assess when making lighting decisions? To begin this discussion, we'll first look at the larger objectives of lighting. With these objectives in mind, we'll look at lighting strategy—how we arrive at the direction, color, and quality of the light for a given scene, and how we light actors' faces. To implement our lighting strategy, we'll also need to understand the technical tasks integral to working in a photographic media, including taking and interpreting light meter readings, using and controlling contrast, and considering the various factors that affect the working lighting level for a scene.

OBJECTIVES

What do we think about as we face an unlit set, before we select and place the particular lights we will use? Take a moment to consider the overall objectives of lighting. The classic textbooks[1] of theatrical lighting design describe four objectives of lighting: visibility, naturalism, composition, and mood. Although the implementation of these concepts is a little different when we are lighting a close-up of an actor's face than when we are lighting a stage, the same objectives apply to our work in motion picture and television lighting. These broad objectives form the basis for lighting decisions as we look at specific issues and techniques later in this chapter.

Visibility (or selective visibility)

A film without sound is a silent movie. A film without light is radio. Obviously, you must have light to expose the film. Exposure and contrast are two essential elements of selective visibility in cinematography. Much of the artistry of cinematography is in the control of lightness and darkness throughout the film's latitude, selectively exposing objects and characters to appear bright and glowing, slightly shaded, darkly shaded, barely visible, or completely lost in darkness, as desired. Equally important is the direction of light. What angle of light shall we use to reveal the face? How much of the face do we wish to reveal? We'll talk a great deal more about exposure and lighting angles later in this chapter.

[1]Stanley McCandless, considered the father of modern lighting design, first proposed many lighting concepts that are still relevant today. His book, *A Method of Lighting the Stage* (1932) discusses the four functions of lighting: visibility, locale, composition, and mood. He also proposed the stage could be broken down into multiple lighting areas, and light could be manipulated in terms of intensity, color, distribution, and control (which will come into play in Chapter 6 of this book). The "four objectives of lighting" also appear in Richard Pilbrow's classic lighting textbook, *Stage Lighting* (Studio Vista, 1970).

Set Lighting Technician's Handbook, 4e. DOI: 10.1016/B978-0-240-81075-1.00005-2

Naturalism

Lighting helps set the scene; it locates the scene in time and space. The quality and direction of the light and the sources it implies are part of what makes a scene convincing. Often unconsciously, we recognize lighting that portrays time, season, place, and weather conditions. The lighting is evocative of the way the air feels and smells, whether it is dusty or clean, foggy or clear, cool or hot, humid or dry.

In lighting a scene, the DP strives to evoke as much about the place and time as he or she can imagine. The crew won't necessarily shoot a given scene at the time specified in the script. An interior scene scripted as "sunrise" could be shot at any time of day or night. To create natural-looking lighting and keep things consistent, one must control the existing light sources and utilize or invent techniques to recreate realistic, natural lighting using artificial sources.

The opposite of natural lighting is lighting that *gives away* the artificial setting to the audience: when the camera records multiple shadows cast on the walls and floor by an actor, when one can trace the diverging rays of light back to a lamp outside a window, when a shot shows "direct sunlight" coming into a room from two opposite directions or at different angles at each window.

Composition

Lighting is used as a means of emphasis and delineation. It helps separate the layers of the three-dimensional world on a flat, two-dimensional screen. It can also create purely graphic effects that contribute to the design of the composition.

Emphasis

The DP selectively emphasizes characters or elements, letting the lighting direct the eye within the frame. For example, imagine a wide shot looking down over the congregation in a large church. The shot immediately conveys the grandeur of the ceremony, but without further help, our eye wanders without a focus. An increased light level surrounding the figures at the front of the church draws the eye to our focal point of the scene, the couple making their vows at the altar. The light falls off on peripheral figures.

Separation

When the three-dimensional world is telescoped onto a piece of celluloid and projected onto a flat screen, our natural stereoscopic ability to detect depth is lost (unless the movie is in 3D). The cinematographer can reemphasize depth in the image by accentuating the outlines of characters and objects, by contrasting the brightness and color of the different layers, and by moving the camera, which reveals depth with the relative motion of different planes.

A common problem is that when foreground and background share the same value, they blend together. The cinematographer may choose to remedy this with a backlight that creates a rim around the actor's hair and shoulders, to separate her from the background. The amount of backlight needed depends on the reflectance of the subject and how pronounced an effect is desired. Backlight has long been an accepted convention in movies and TV, however a really bright glamorous backlight can also appear really artificial. Strong backlight can be made to look natural if it is well motivated. A bright window in the background of the shot helps in this type of situation; it provides a sense of source.

Backlight is not the only way to create separation. The cinematographer might choose to separate the foreground, middle ground, and background simply by lighting them to contrasting levels of

brightness. He or she can line up a highlight in the background so that the dark side of the actor's face is against a light background. The highlight need not completely light up the background if the DP wants to maintain a sense of darkness. You can selectively throw a shaft of sunlight, or a pool of light around a practical, or a slash of light across some wall art, so that it lines up behind the actor in a pleasing composition, leaving contrasting shade around it. You can also use a light dose of smoke in the air to give substance to a translucent shaft of light, leaving the background in atmospheric dimness behind it.

Depth

Another important compositional element is depth. A composition that includes surfaces at various distances receding into the distance increases the shot's sense of perspective and scale. If the shot includes some sense of space beyond the plane of the facing wall, outside a window or through an open doorway into other rooms, the gaffer can create planes of light and dark that recede deep into the picture. Depth offers nice opportunities for interesting lighting and composition.

Graphic effect

A DP often wants light that simply creates graphic shapes or lines that enhance or distort shapes in the scenery. This could be done by throwing a diagonal slash across the background, a pattern of moving foliage, a window frame, a Venetian blind, or by using objects in the set dressing to create irregular shadows.

Lighting a textured surface at an oblique angle emphasizes the texture of the surface. The wall of a corrugated metal building appears as a pattern of vertical lines; a brick wall becomes a pattern of regular rectangles. Breaking up the background with textured light goes a long way toward creating an exciting image from one that would otherwise be dull.

Mood

Mood is perhaps the most powerful contribution of lighting to a motion picture. In collaboration with the director and production designer, the DP considers the script: the events, the emotions, and the personalities that inhabit the space in the story. He or she arrives at a sense of what each scene should feel like. The lighting may be gritty and hyper-realistic, slick and clean, high-tech and stylish, or lush and glamorous. It may be naturalistic or it may be stylized or theatrical. DPs often find it helpful to formulate conceptual ideas that can inform and inspire their approach to the lighting. These arise from questions like:

- What kind of world does the story exist in? What kinds of images convey the basic tone of the film?
- What color and quality of light supports the character's inner emotional state, and what light sources could be introduced in the scene to motivate that light on the actor or in the room?
- How should the audience experience this character—radiant with charisma, frazzled and imperfect, strong and determined, or what?
- What are the conditions, the weather, the time of day? Are they dictated by the script? If not, does the tone of the scene suggest an approach to take? The lighting does not necessarily follow a literal interpretation of the script's mood. It can be ironic—a miserable lonely person faced with a beautiful sunny day.

- How is light treated by the character in the story? Would she invite sunlight to pour into the room like butterscotch or close it out, leaving us in a musty dark room, the sunlight seeping around the edges of thick curtains?
- Does light connect the central character to his surroundings or does it isolate him? Is he surrounded with glowing human faces with whom he might interact, or anonymous figures who leave him alone and alienated?
- Where does the arc of the story take us? How does the space change in appearance and feel from one part of the film to the next? Is it a long day's journey into night, an emergence from darkness into light, or what? How will each scene in this progression be augmented?

Infinite creative possibilities wed the lighting to the story. New ideas constantly suggest themselves from the dialog, the setting, and the actual location. Even the props, the set dressing, and the characteristics of the actors themselves can contribute to lighting ideas. Very often on location scouts, the natural fall of the light lends itself to a particular scene, stimulating ideas for how that feeling can be recreated. A set painter's work light might do something interesting quite by accident.

Imaginative previsualization of each scene, based on story-driven concepts, stimulates an inexhaustible supply of lighting ideas. It brings variety to the cinematography and avoids a formulaic approach. It offers the DP and gaffer a cohesive vision, which will result in creative, effective, and appropriate lighting design. All of the decisions we have talked about so far—the extent to which elements of the scene are visible, the realism of the lighting environment, the specific compositional elements—the sum of all of these details is an overall mood. Every decision the DP makes contributes something to the image. The DP's imagination and sense of taste align each decision with the director's vision of the story.

Time constraints

One final objective that has been conveniently ignored thus far is working within the time frame permitted by the production schedule. In an ideal world, the DP could devote planning and attention to every detail, and the crew would have all the time needed to rig and tweak the lighting. In real life, however, speed often becomes the top priority, and the lighting has to be designed accordingly. When nothing more specific has been planned, DPs can always rely on one of a handful of generic lighting formulas, which can be tailored to the scene and will look good. Sometimes it feels like we only have enough time to eliminate the really horrible problems, and once that's done, we shoot. The lighting crew spends all its energy trying to get out of the fire and back into the frying pan. Nonetheless, even under the worst of circumstances, the DP and gaffer aspire to make choices that address the four lighting objectives of selective visibility, naturalism, composition, and mood in order to arrive at an image that is more than merely acceptable, but photographically evocative, and sometimes even striking and memorable.

THE PROCESS OF FORMULATING A LIGHTING STRATEGY

It is helpful to think of the lighting as two related endeavors—lighting the actors, with special attention to their faces, and lighting the scene, by which I mean the room or space and background. The *key light* is the strongest light on an actor's face, and placement of the key lights is one of the DP's first concerns when lighting a scene. The motivation for the key light on the actors will be influenced by the approach to the overall scene, and it may happen that the lighting of the space takes care of

the actors, too. However, the DP's decision as to the lighting direction for the actors is also strongly influenced by the direction the actors face during the scene, by which directions they turn to look, and by the inclination of their head. The DP and gaffer observe these details closely during the rehearsal, and choose the lighting directions that best serve the blocking[2] and behaviors the actors will perform. So in most cases, the DP begins by lighting the faces. It sometimes happens that this light also lights the scene, but just as often this light must be modified—cut off the walls, for example—so that the layers of the image are separated.

Sometimes a DP will reverse the approach by primarily lighting the space, adding to it only where necessary to ensure some exposure on the actor's faces. This approach tends to work well for low-key naturalistic scenes. In this scenario, the DP is making a conscious effort to avoid an overly polished or contrived look, in favor of realism and grit. Strong "ideal" key lights can threaten to over-light a low-key scene. This approach may result in some unconventional lighting angles, such as lighting with bounced light from below, or with top light. How far the DP wants to take this idea depends to a large extent on the type of show it is. In some productions, the DP must remain fairly conservative about lighting actors from angles that are unflattering, but for others, realism and the emotional potential of the lighting trumps all.

The DP forms a lighting strategy thinking about two things: (1) the camera position of the forthcoming shot, choosing the lighting directions that best serve that shot, and (2) mentally applying the resulting lighting strategy to all the other camera angles that are likely to follow. The DP wants to take a moment to think ahead, to imagine how the lighting will be adjusted in other angles to ensure that he or she can maintain lighting continuity, and not light him- or herself into a corner. The DP tries to anticipate the major lighting arrangements for the entire scene, because it may influence shot order and other matters of efficiency. As you can see, the DP is taking many things into consideration when beginning a lighting setup.

Another critical ingredient to the process of lighting strategy is identifying the motivating light sources for the scene. The motivating source of light may be real or may exist only in the imaginations of the DP and gaffer. Identifying the motivation for the light brings realism to the lighting. The motivation for the light in a scene might be direct sunlight pouring through the windows, or the glowing soft light of sunlight bouncing off a surface. It might be light filtering through a skylight, candles on a dining room table, a table lamp, streetlight, moonlight, torchlight, the light of an instrument panel (in an airplane, a car, a spaceship, a submarine), a flashing neon sign outside the window of an urban apartment, the flashing lights of an ambulance, the headlights of a passing car, or the flickering glow of a bonfire on a beach. The *color* and *quality* of the light is manipulated to emulate that of the motivating light source and, of course, when the key light has an identifiable source, the light must also emanate from more or less that direction—although a great deal of license may be taken. As mentioned before, the exact *direction* of the key light is typically manipulated to what looks best on the actors' features for the given blocking and camera position. A large motivating source, like the sun, may be emulated with several large lights pouring in through different windows. On the other hand, it may be that a number of different sources will motivate lights in different areas of the set. For example, as an actress moves from a window to a sofa in front of a fireplace, she walks out of the soft, blue window light and into the warm, flickering firelight. Even subtle differences in the color and quality of light sources make the lighting

[2]*Blocking* refers to the placement and movement of the actors in the acting space over the course of a shot, or scene.

more convincing. Motivating the color of light sources also provides the DP a way to separate layers of foreground, middle ground, and background. This is known as *color separation*. A fluorescent light source might be slightly blue, or slightly green; a window light might be slightly amber (sunlight), or slightly blue (skylight), and so on.

In most cases, if the motivating source is seen on camera—a practical lamp for example, or window light streaming through sheer curtains—if the source is bright enough to illuminate the actors, the source itself will be too bright; that is, blown-out white with no texture remaining. Suppose that an actor is sitting on a couch beside a table lamp. If we rely solely on the lamp to provide the exposure on the actor's face, the lamp will be greatly overexposed. Conversely, if we dim down the lamp so the lampshade has good detail, it will fail to provide sufficient illumination for the actor's face. The actor's face therefore needs to be illuminated separately by a source that mimics the soft, golden quality of the table lamp. This also affords us the opportunity to "cheat" the key light where it will look best on the actor's face. What matters is that the quality of the light—of the key source in particular—be that of a realistic and plausible lighting source. A diffused Fresnel aimed around the front of the lamp would serve this purpose. Care must be taken not to let light spill onto the lamp itself or to let the lamp cast a shadow from the Fresnel, as this would destroy the illusion of light originating from the lamp.

During preproduction, the DP, the production designer, and the director may discuss the movement of the actors in relation to the placement of lighting sources. Light naturally influences behavior. For instance, a patch of sun moves across my living room floor during the afternoon, and my cat moves every 15 min to keep up with it. People also gravitate to light to read, work, and talk to one another. It is therefore natural that the lighting fall into place with the blocking, and to some extent, the director and production designer will want to place the furniture, windows and light sources to facilitate lighting the action.

When no plausible sources exist to light the actors, as in a dark bedroom at night, a little dramatic license must be taken. The idea is to create a look that is psychologically palatable to the audience, if not wholly realistic. For example, one approach to lighting a supposedly unilluminated night scene is to create a low base level of nondirectional blue light and underexpose it. Then, very selectively, add chips and slivers of light, and perhaps use subtle backlight to define the contour of the actor where he or she disappears into dark shadow. The success of such an effect is a delicate matter requiring an experienced eye and judgment.

For a given scene, the DP often has many different possible motivating sources to choose from. He or she chooses the ones that fulfill her lighting objectives for the scene. Taking into account the specific blocking, architecture of the set, and placement of practical lights in the set, the DP decides which source will motivate the key light on the actor's face, which source to use to motivate backlights, which sources might motivate lighting on the background, and so on.

Key light: Lighting the actor's face

As we have said, the DP typically chooses the key light position that *best* lights the actor's face. This raises the questions: What is the effect of choosing one key light position or another? What criteria does the DP use to decide what is "best?" Although there are no hard and fast rules, we can make certain observations about the way light interacts with the human face.

Rembrandt cheek-patch lighting

The shape of a face is revealed to the eye by the way light falls on the curves and planes of features. Tonal variations—the shading and shadows—tell our brains the shape of an object. Certain features

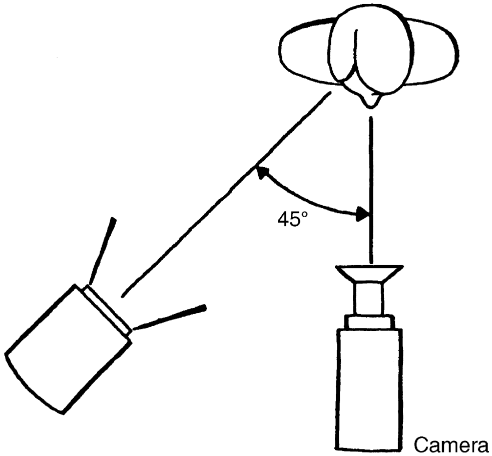

FIGURE 5.1

Conventional key position, 45° above and 45° to one side of the actor.

can be emphasized or deemphasized by the placement of the lights. The conventional, textbook key light position is at 45° above and 45° to one side of the actor (Figure 5.1). This position throws the shadow of the nose across the opposite side of the face, leaving a patch of light on the cheek. This patch is known as the *Rembrandt cheek patch*, after portraits by the seventeenth-century Dutch painter. This lighting angle puts light in both eyes and models the nose, lips, chin, and cheeks nicely. It is considered the most natural key light position. However, every actor has different facial features: one has a large nose; another has a broad face or a chin that sticks out or droops. Some have deeply set eyes that are difficult to get light into, or hair that interferes with the light, or wrinkles we wish to hide. The DP responds to these differences in the treatment given to each face; the 45° rule quickly becomes academic.

Most often, the key is somewhere between 0° and 90° from a frontal position to the subject and between 0° and 45° above the subject's head; however, it can come from any direction that reveals at least some of the features of the face: from below, from high overhead, and even from a three-quarter back or side position.

All things being equal, it is photographically more pleasing to light with a *far-side key* than a *near-side key*. This is an important concept in selecting the key light position. When the camera faces an actor in typical coverage, the actor looks either camera left or camera right, so his face is not completely straight on to the camera, but slightly one way or the other. If an actress faces toward camera left, she presents more of the right side of her face to camera than the left side. The left side is therefore the *far side* and the right side is the *near side*. A far-side key light lights the far side of the face, allowing some shading to fall across the near side of the actor's face (Figure 5.2A). This arrangement models the facial feature by presenting contrast (created by the shadow line of the nose, lips, eyes, jaw, chin, etc.) toward the camera.

If we do the opposite, placing key light on the near-side (camera right in this example), we light the side of the actress's head rather than her eyes and face; the nose shadow falls across the far side

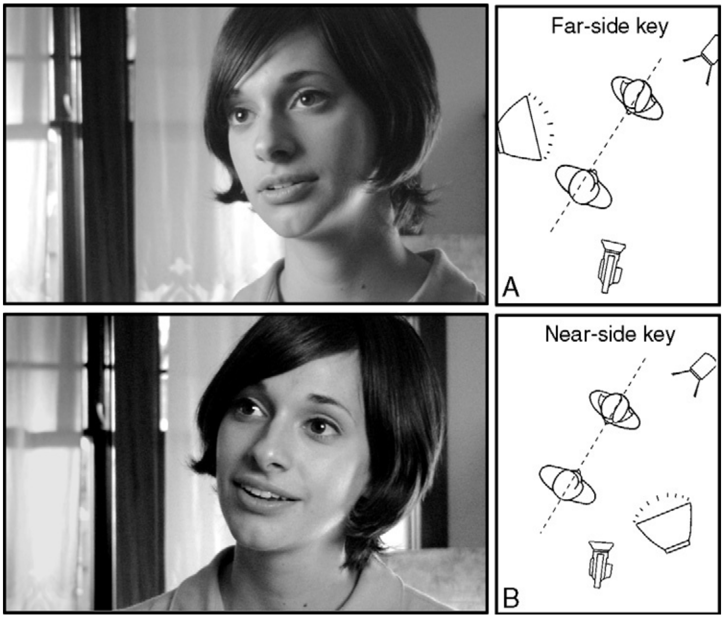

FIGURE 5.2

(A) Far-side key (key light is on the other side of the line of action); (B) near-side key (key is on the same side of the line as the camera).

of the face where the camera won't see it as well and the predominant side presented to camera is in front light, generally flatter and less appealing (Figure 5.2B). Placing the key light on the side opposite from the direction the actor is looking is called placing a *near-side key*, which some people like to call the *dumb-side key*. There are of course plenty of situations where a near-side key is used. Sometimes it is necessary. Sometimes it looks completely natural and is even preferable. No one has ever been denied a Best Cinematography Oscar because they used a near-side key; however, the preference for a far-side key is the foundation of many a lighting setup.

Side light

If we move the key light deeper, more around to the side, it no longer reaches around the face to light the far cheek and into the far eye (Figure 5.3A). A direct side light at eye level puts one whole side of the face in shadow. When this half-light effect is desired, the best position for the key light is not at 90° to the face but slightly less than 90°. At 90°, the cheek on the key side of the face tends to make an unattractive shadow. By bringing the light slightly forward of 90°, the shadow disappears, and the result is a pleasing half-light effect. It models the face nicely and gives a pronounced sense of contrast and direction. As people age their facial features grow more prominent. Side light tends to accentuate the features. Young children's faces tend to have less predominant features and a soft side light easily wraps around their faces. In Figure 5.3B the key is able to wrap onto the far cheek.

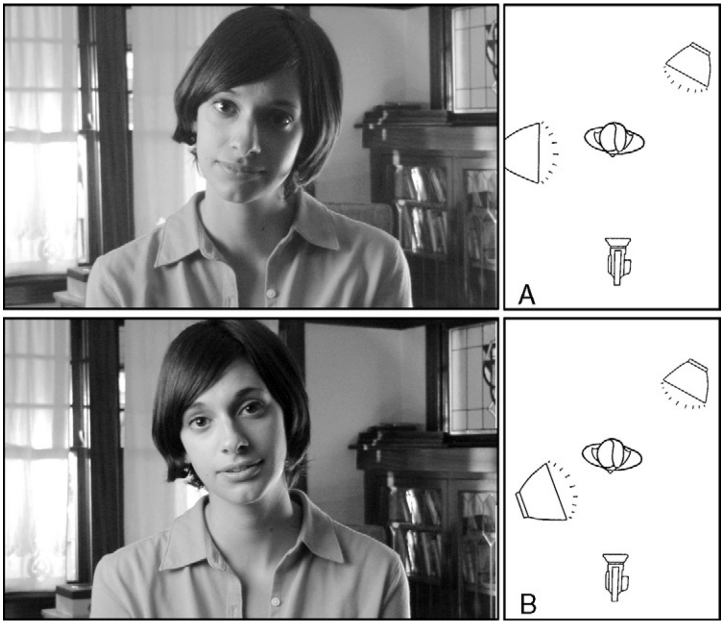

FIGURE 5.3

(A) Side light with opposite side kicker; (B) same setup with soft wrapping key.

A nice addition to a side light key is to use a second light to "wrap the key" around onto the far cheek with a second soft source in a three-quarters frontal position on the same side as the key with little or no additional fill. This lightens the face without over-filling from the front, and results in a very soft side light, with rich contrast and a subtle gradation of tones from light to dark across the face.

Figure 5.4 shows an actor facing three-quarters to camera. From the camera's perspective, the key light, which is lighting one whole side of the actor's face, is a deeply set side light. By

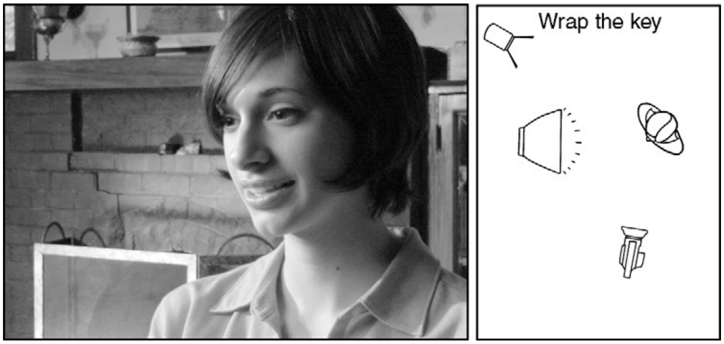

FIGURE 5.4

Deep set, far-side key with soft wrap.

wrapping in a limited amount of soft fill light, one creates a pleasing gradation of tones with rich contrast and the light sources are seamlessly blended.

One pitfall of a side light position is that, if the actor turns his head away from the source, the face goes completely into shadow. The addition of a back or side kicker on the non-key side can help define the features in such a case (as was done in Figure 5.3). Alternatively, you could let the face go dark and define the profile by silhouetting it against a lighter background.

When two actors are side by side, an eye-level side light tends to cast the shadow of one actor onto another. This problem can be remedied by raising the light higher, throwing the shadow downward.

Front light

If we move the key light over next to the camera, in a more frontal position, the actor's nose shadow gets smaller and smaller and the whole face comes into light. Facial features are given less shape by the light. The image appears bright and "flat." Front light was a convention of glamour cinematography of the black-and-white era. By placing the light so that it shoots dead onto the face, the nose and chin shadows are minimized to a small underline. The eyes appear very bright, and the sides of the face, the temples, and jaw fall off in brightness. To prevent the front light from flattening out the entire scene, it is often desirable to angle the light down such that it can be cut off the background with toppers and siders (Figure 5.5).

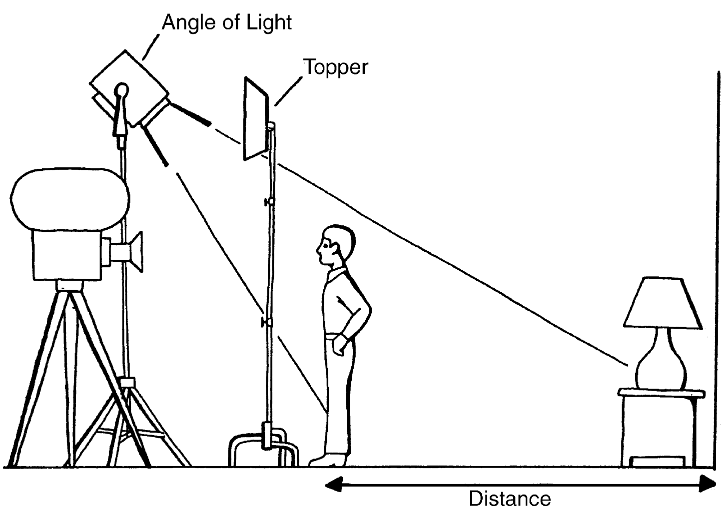

FIGURE 5.5

An on-the-nose key usually requires a topper to prevent the front light from flattening out the background. It is also helpful to have some distance between the actor and the background; otherwise, a hard shadow becomes unavoidable.

Glamour photography commonly uses a large frontal soft light close to the actor's face. The goal is to reveal less of the form (make the nose look smaller) and to fill in the blemishes. Actors who have undesirable wrinkles are often given stronger doses of super-soft front light. Without question, it is part of the DP's job, in most instances, to make women look beautiful.

On the whole, front light flattens the image. It prevents the image from revealing shape, form, texture, and contrast. However, there are ways to use frontal key light with great effect, and mitigate the flattening effect by using a little finesse. When front light threatens to flatten out the entire shot, we can break it up with a top cut or breakup pattern. For example, if the scene is established with strong sunlight coming into the room, and the camera angle is such that the sunlight is now frontal, a common technique is to make a hard cut using either a diffusion frame, or a solid flag, cutting light off the actor's face. The cut might be positioned just below the nose, leaving hot light on the mouth and chin, or positioned lower, at the sternum, cutting it off the face all together. This gives the impression of strong sunlight, while softening and reducing the light on the face. The actor's face, now in shade, can then be lit from a more pleasing key position, motivated as soft reflected light from the sunlight landing on surrounding surfaces. Often, a subtle bounce board is all that is needed to lift the face. In this way the DP cheats the light, to make it more ideal.

Bottom light

The thought of frontal bottom light conjures up images of an eerie, unnatural visage with lighting under the eyebrows, nose, and chin casting shadows upward from the eyebrows. However, a low light source does not necessarily have that effect. Light that is bounced up from a light-colored floor or table surface can lend the face a soft radiance.

Naturally, a low position may be used when a light source is at ground level (a campfire, for example) or the actor is elevated. Any time you place a light in a low position, you have to be prepared to deal with, or learn to love, the shadows cast upward on the background and ceiling.

Placing soft or bounced light on the ground from the side and three-quarter back position highlights the line of the neck and jaw and the edges of arms. This is a fast way to get some nice definition without having to worry about the lights getting into the shot. If the lens has a narrow angle of view (doesn't see below the waist) or the set dressing can provide hiding places for low lights, this can be a great, fast option. Kino Flos placed on the floor, small tungsten soft lights on the floor, or PAR cans bounced onto a white show card lying on the ground—all these techniques achieve similar results. A floor-bounce also works well for a touch of frontal fill.

High in front or high to the side

A high position can give a dramatic effect by putting the eye sockets in deep shadow and underlining the nose, lips, and chin in shadow. In *The Godfather*, Gordon Willis used soft, high frontal sources to give Marlon Brando a low-key, intimidating presence. In this instance hiding the actor's eyes made the character more mysterious and menacing.

Although high front lights can have a powerful effect, for everyday scenes this is not typically the desired one. Typically when a location or set has strong overhead light sources (from practical lights such as can lights, fluorescents, or sunlight) we try to soften or eliminate the down-light hitting the actor's face. The grips can rig a flag or diffusion frame over the actor's position, or the electricians can unscrew the offending lamp, of turn it off.

THE LIGHTING TRIANGLE

We have been discussing key lighting positions—the brightest light lighting the visible area of an actor's face. To this light, we add some amount of fill light to lighten the shadows caused by the key light. In addition, we often choose to add back lights or edge lights to help separate the actor from his or her background, and sculpt shape of the actor's face, body, and wardrobe. As it happens, these three lighting directions—key, fill, and backlight—often form a triangle around the actors.

Fill

The object of fill light is to bring up the light level in the dark shadow areas of the face created by the key light. To do this, soft light must come from a more frontal position than the key light, usually from near the camera. When low light levels are used, the ambient light level may be sufficient to fill the shadows; often the fill can be accomplished with a white board placed to bounce light into the shadow areas of the face. When a fixture is used, it must be a large, soft source that will not create additional shadows—a light bounced into a 4 × 4-ft. piece of foam core or put through heavy diffusion such as 216 or a large source such as a soft light, chimera, or other soft box.

The amount of fill light determines the contrast ratio and has a great deal to do with the apparent lightness or darkness and, to some extent, the mood of the scene. If the fill light is strong, the scene appears very bright and flat, a look termed *high key*. Reducing the amount of fill light brings out the directionality of the key lights, separates the elements of the frame, and makes the colors appear more saturated. Reducing the fill even more allows deep shadows to appear. A high key/fill ratio gives the sense of night or darkness in the room, especially if the scene is lit with edge and side light. This kind of look is termed *low key*.

Most DPs fill by eye rather than by using a meter. It may be helpful to turn the fill light off and on to judge its effect. Judging fill light takes some experience and familiarity with the characteristics of the film stock. Of course, when shooting in High Definition (HD) video the DP typically has a high quality monitor on set and can directly assess how the lighting contrast is being interpreted by the camera and video processors.

In some environments there is so much light bouncing off the surrounding surfaces that there is too much fill and it actually becomes difficult to achieve contrast. In this case, the grips can help by providing some "negative fill," 4 × 8-ft black frames (floppies) that can be placed to block the ambient light filling from one side.

Eye light

An eye light is a very specific kind of frontal fill light. It makes the eyes twinkle by creating a reflection in the eyeball, and also fills the shadows under the eyebrows. The light is usually placed as close to the camera lens as possible. The bigger the dimensions of the source, the bigger the reflected dots. Eye light does not have to be very intense, however, because the eyeball is very reflective. An eye light need not flatten out the overall composition.

An *Obie light* is a light positioned directly over the camera lens, mounted to the matte box. It has the advantage of panning, tilting, and dollying with the camera. The Obie light maintains a minimal level of frontal fill on actors as they pass in and out of other lights while the camera moves with them through a set. An Obie light typically has some sort of dimming device. It is convenient to use

dimming shutters or a dimmable fluorescent or LED light (e.g., a Diva-Lite 400) so that brightness can be adjusted without affecting color temperature.

Camera-mounted lights are often helpful when tracking actors through caves, corridors, air ducts, or tunnels when the overall feel needs to remain dark but a minimum amount of fill light needs to be maintained on the faces.

Backlights, kickers, and hair lights

Backlight highlights the edges of the face, hair, and shoulders of an actor. It strengthens the lines that delineate the figure from the background. The various backlight positions can also emphasize features of the face and hair. Scenes that occur in relative darkness are often backlit to give delineation to the figures and set dressing without lighting them too much from frontal angels. Backlight is also the best angle to make rain and smoke visible to the camera.

Three-quarter backlight kicker

A kicker is normally relatively low, from a three-quarter backlight position. A light glancing off the side of the face and hair gives form to the jaw, cheek, and hair and separates that side of the figure from the background. If the actor turns profile to the camera, a three-quarter backlight highlights the profile, and can even act as a key light. Because of its low, back position, it does not cause problems by spilling onto walls and can easily be kept off the ground. As with all backlights, the problem is always keeping it out of frame and preventing flare on the lens. It is nice to be able to hide the light behind a set piece or furniture.

High side backlight

High side backlights, one on either side of the subject, soak the performer in backlight; the effect is powerful and dramatic. You see this technique used in rock concerts and dance performances. When blended with the frontal lights and applied with more subtlety, a pair of high side backlights rims the head and shoulders evenly and highlights the hair. News reporters and talk show hosts seem to have one or two backlights with them wherever they go. High backlights tend to light up the ground, tabletops, and other horizontals.

Rim

A rim light is a high direct backlight that rims the head and shoulders, pulling the actor out from the background. A rim light is a thin highlight. Again, the light spills onto the floor and must be shaded off the lens.

Hair light

Positioned somewhere between a rim and a top light, a hair light creates a flattering halo effect. Applied with subtlety, it brings out the color and texture of the hair.

Top light

A top light (directly overhead) primarily lights the actor's hair and shoulders. It does not light the face at all, other than the forehead and the bridge of the nose. Although it can be used for dramatic effect, this is not a great position from which to light a person, unless the person is reclining. It can be effective to create a sense of faceless, anonymous figures in a room, lighting tabletops and horizontal surfaces, without illuminating faces.

LIGHTING THE ACTING POSITIONS

Let's look at how these lighting angles come together to light a scene with several actors interacting. The scene shown in Figure 5.6 shows Andy standing opposite Babette and Camile. Babette and Camile are lit with a strong soft key light from the left. The first shot is a master that holds all three actors in a three-shot with camera positioned as illustrated. With Babette looking left to Andy, the key light hits Babette's face as a nice far-side key. Camile faces more toward the key light. It illuminates most of her face. The key light does not light Andy's face at all, his back is to it, but we carve out his profile with the three-quarter backlight from the right. This backlight is also creating an edge around the camera-right side of Babette's and Camile's heads and clothing.

These three basic lighting angles can create many different looks. The relative strength of the three sources shown here, and also the color of each source, could be played in many different ways. For example, the big soft light at camera left can be played as the strongest source, warm soft window light, exposed perhaps 1 stop over the aperture setting on the camera, with a warm gel (¼ CTS is a straw-colored color correction gel that is great for this) on the light. The backlight from the right is played as a weaker bluer source, ½ stop under exposure, with a pale blue gel (½ CTB). The fill light is played 2 stops under exposure. The result will be a warm light scene with rich contrast.

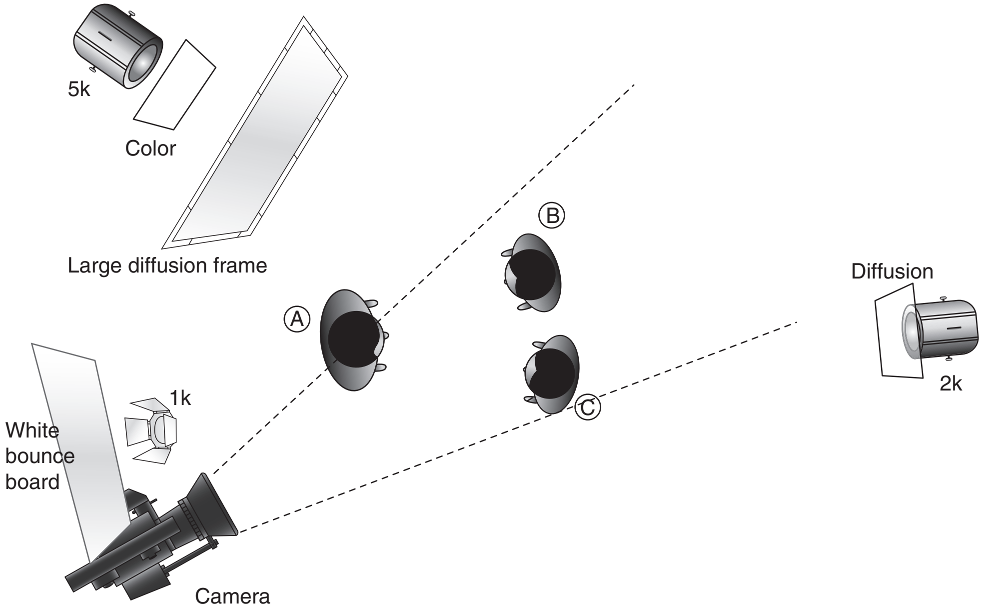

FIGURE 5.6

During rehearsal, the DP notes the direction of the actors' faces, and finds a key light angle that accommodates both of them. Here the body language favors putting a large soft key from camera left. Both faces are modeled nicely from this angle.

On the other hand, imagine what the scene would feel like if the big soft source could be played as a weak light filtering in through shades, exposed a stop under exposure and cool blue (¾ CTB). Imagine that the backlight from the right plays as direct sunlight through a window, neutral in color and bright (2 stops over exposure), and the fill light is neutral in color and exposed 2½ stops under exposure. The impression now is totally different. The room feels dim, and moody.

Back cross-keys

In a scene with two or three actors facing in various directions, the key light for one actor may well serve as a backlight or edge-light for another actor. Here again it often happens that the primary lights form a triangle.

When two actors are facing one another and the camera is shooting them in profile (a 50/50 shot), or close to it, a common lighting strategy is to use a *back cross keys* (Figure 5.7). Actor A is keyed from the back right, actor B from the back left. From the camera's point of view, these two lights are far-side key light for each actor. When shooting a moody, dark scene or night scenes, the key lights often move around to side and back positions. However, the back cross-key strategy is used in any number of situations. Multicamera sitcoms often employ this strategy, because the proscenium-style shooting lends itself to blocking where the actors are facing one another in profile to the audience.

Figure 5.7 shows the camera position for the master shot has both actors in profile. If this were a dark night scene, the fill level would be kept very low, putting very little light on the visible side of either actor's face, giving a sense of overall darkness. Note that actor B's key light acts as a kicker, or backlight, for actor A, and actor A's key light does the same for actor B.

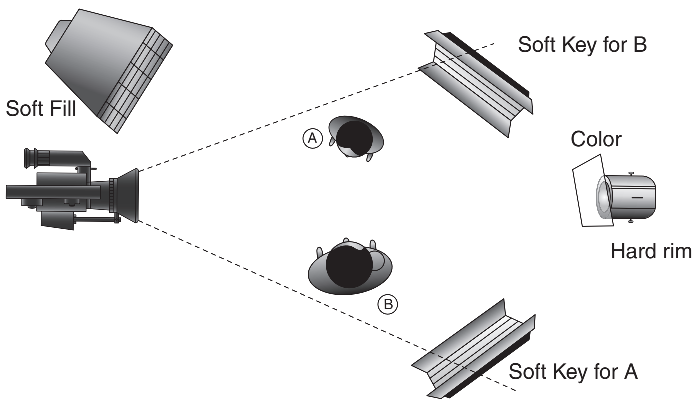

FIGURE 5.7

Here two actors are facing each other, profile to the camera, and each has a far-side key light (in this case, two fluorescent banks). This lighting setup is known as "back cross keys." In this illustration, the soft wrapping light of the fluorescents is augmented with a direct hard backlight "liner," which puts a bright highlight around the actors' profiles.

A small amount of fill light is required to keep the side of the faces visible to the camera from going totally black; however, the fill light's intensity must be very carefully controlled to get detail in the faces without overfilling. The fill light is drawn as a soft light; the fill light for a large night exterior is often made by bouncing light into a 12 × 12-ft white griff or provided by ambient light from an overhead light such as a balloon light. Similarly, the key lights might actually be large lights placed far from the action, often mounted in an aerial lift platform to light a larger area. In any case, the back cross-light is created with more or less the angle of light drawn here.

Once the master shot is completed, individual, over-the-shoulder (OTS) close-ups will be shot. Figure 5.8 shows the camera placements. Note that our key lights are already in good positions to light the faces. We might bring in a backlight to keep a rim on the non-key sides of the faces.

The discussion thus far has dealt with lighting a stationary group of actors and a stationary camera. Very few movies, however, are about people who never move. We apply the same basic mental process that we have been discussing to concoct a strategy for lighting a complex shot. When the actors move to multiple marks and the camera moves to view the scene from different angles the variables increase; however, we can usually break down the scene into a series of key positions. We can choose to light each of these key positions individually, or we can take a more general approach to the lighting, and employ larger key, fill, and backlight sources to illuminate a larger area. If a light that plays in one part of the scene is too much or too little for another part, perhaps it can be adjusted imperceptibly on a dimmer, or using a handheld net during the action. This is where the problem solving abilities of the DP, the gaffer, and the key grip come to bear.

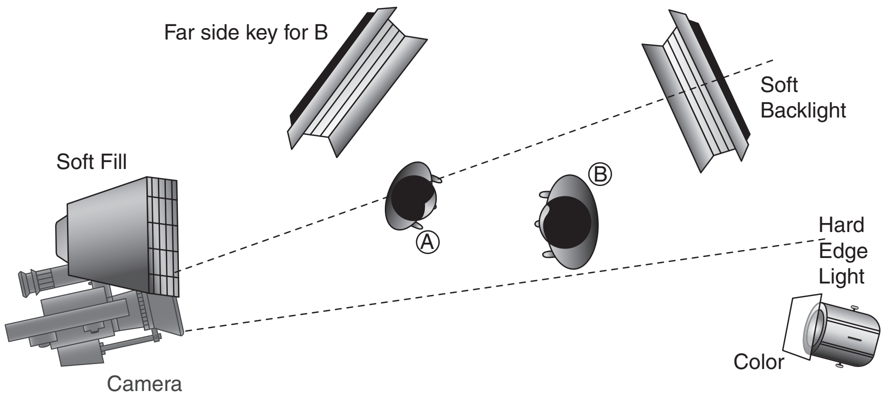

FIGURE 5.8

The setup changes very little from Fig. 5.7 when the camera goes in for over-the-shoulder (OTS) coverage. Actor A's key light (in Fig. 5.7) now serves to edge-light both actors. It is easy to forget to provide an edge for the foreground actor when you are concentrating on lighting the actor facing the camera, but without it, the picture can look incomplete when reverse close-ups are edited together. Note also that in this case the liner is cheated around to the non-key side.

LIGHTING THE SPACE AND THE BACKGROUND

In addition to lighting the acting positions, we want to consider the lighting in the overall composition: the furniture and surfaces, the walls and architecture, the wall art and set dressing, and the exterior visible through windows buildings, trees, or backdrops. In a small set, the key lights may illuminate the set and very little further treatment may be needed. If you are trying to preserve nice contrast in the shot, it is often best to be selective when adding light to the background. Light tends to build up on backgrounds and can start to flatten everything out. The gaffer looks for ways to break up the background or create variation, gradation, or specific highlights. If a scene takes place in a set with lots of windows, it is natural to scrape a slash of sunlight across the far wall, and across the furnishings. Large Fresnels or PARs are commonly placed outside windows for this purpose. Alternatively, the light from the windows might be made to emulate soft skylight, using large diffusion frames or bounces. At night, window light might be amber sodium vapor streetlight, or blue moonlight.

Another treatment of the background is to create pools of light throughout a set. The background may be lit with practicals. In a set with lots of desks or a restaurant full of tables, each table might get its own top light (from an ellipsoidal spotlight hung overhead for example). If there is art on the walls, the gaffer might highlight each piece with a "special." If the walls are painted a dark color, the gaffer might wash light either upward from the bottom or down from above to create pools or scallops of light.

Ambience

Ambience is general fill throughout the set (as opposed to the fill specifically for the actors' faces). All the light aimed into the set bounces around to some extent to create a level of ambient light. But sometimes the setting requires a higher, more even level of ambient light. This is commonly accomplished with overhead soft lights such as coops, space lights, or large fluorescent fixtures hung above set. For a living room set, one overhead fixture is more than enough; for larger sets, it is common to hang rows of spacelights. Any large public space, like a courtroom, corporate office, or a classroom might need to be treated in this way. Exterior portions of sets (that are built on a sound stage) often require a significant amount of ambient light to emulate skylight. Wherever it is used, it is important to be able to adjust the brightness of the ambient light, so these lights are typically controlled remotely either on dimmer, or by having separate control of the circuits each light fixture. On smaller sets, it may be helpful to fit the fixtures with lower wattage lamps (500 W instead of 1000 W, for example) to get an appropriate range of output for the small space. Ambiance for a small set can also be created using china balls or by simply bouncing light into the ceiling, or into a large frame of white griffolyn.

Backdrops

A translight is essentially a gigantic photograph. On a sound stage, the scene outside the windows is very often a translight or scenic backing (painted backdrop). Day and night translights are commonly used depicting a backyard, the view from a high-rise office building, or what have you. The backing is usually backlit or frontlit with sky pans on 8-ft. centers. The main objective when lighting

backings is to make the light even from one side to another. Backings are often hung from track, so the backing can be moved back and forth depending on the camera angle. The lights have to extend the length of the track.

Often the gaffer will set some special lights on the backing to help bring it to life. For example, a night backing often shows buildings with lit windows. These can be made to look like an undulating television glow by isolating the window and hitting it with a blue-gelled light connected to a flicker generator. A translight that shows a body of water can be made to shimmer using rotating gobos or moving lights effects.

QUANTIFYING BRIGHTNESS AND CONTRAST

Exposure

An incident light reading can be expressed one of two ways, in foot-candles (FC) or f-stops. Thinking in foot-candles has advantages when working with the lights, but ultimately, the f-stop is set on the camera, and most DPs think of their exposure range in terms of f-stops.

Foot-candles

A light reading expressed in foot-candles is an absolute measurement of light level. A light reading expressed in f-stops depends on additional variables (the film speed, shutter angle, frame rate, filtration, and so on). A light meter, such as the digital Spectra Professional IV (Figure 5.9), can tell you the intensity of light in foot-candles (Figure 5.10 shows the foot-candle scale). This meter also gives the reading as a working f-stop, taking into account the film ISO and shutter speed.

The advantage of working in foot-candles rather than f-stops is that a gaffer knows (or very quickly learns) how many foot-candles to expect from a given light at a given distance (Table 5.1 lists some approximate data; Table A.3 is a more comprehensive list). If lighting to a given FC level, the gaffer will always call for the right light for the job; f-stops, on the other hand, do not correspond directly with light level. It is not as straightforward to know what light fixture will give a particular f-stop.

F-stops

Settings for f-stops are inscribed on the aperture ring of the lens of the camera by the manufacturer in standard increments: 1, 1.4, 2, 2.8, 4, 5.6, 8, 11, 16, and 22. Figure 5.11 shows the entire range of f-stops and the increments between f-stops. The lower the f-stop, the larger the aperture and the more light passes through the lens. The range of f-stop on a given lens depends on its design. A lens designed for speed might open up to f/1. An extreme telephoto lens might open up to only f/5.6.

A light meter gives the f-stop by taking into account the film speed and exposure time. (For normal filming at a crystal sync speed of 24 fps and with a standard 180° shutter, the exposure time is $1/48$ seconds) The f-stop scale in Figure 5.12 shows how foot-candles compare with f-stops for 320 ISO film. As you can see, the foot-candles double with each f-stop. Each incremental f-stop cuts the light by a half: f/4 lets half as much light through as f/2.8, so it takes twice as many foot-candles at f/4 (64 FC) to get the same exposure as at f/2.8 (32 FC). Table 5.2 correlates f-stop to foot-candle level for all film speeds.

FIGURE 5.9

Spectra Professional IV digital/analog light meter. This meter reads incident light directly in f-stops and photographic luminance in foot-candles or lux, with a range of 0.1–70,000 FC.

(Courtesy Spectra Cine, Inc., Burbank, CA.)

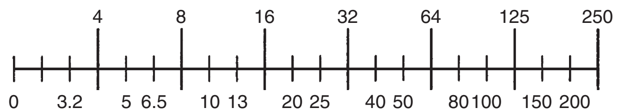

FIGURE 5.10

The range from 0 to 250 fc encompasses seven stops (divided here into 1/3 stop increments). Note that foot candles double with each stop.

Taking readings with an incident light meter

Incident light meters measure the amount of light falling on the face of the light meter. A *hemispherical light collector*, or *photosphere* (commonly known as *the ball*), collects light from the sides, top, and bottom as well as the front. The reading is taken by holding the meter up in the position of the subject. When the ball faces the camera, the meter gives an average reading of the total amount of light falling on the subject as viewed from the camera.

Alternatively, by pointing the ball at the light source, you can read the amount of light from that source. However, keep in mind that when light hits the subject from the side or back, relative to the camera, less light is reflected toward the camera than when that light hits the subject from the front.

Table 5.1 Relative strengths of various sources

Source	FC spot	FC flood
Direct sunlight		6400–8000
Skylight on an overcast day		450–1800
Brute arc at 30 ft	9000	1190
12k HMI at 30 ft	8250	500
9-lite PAR 64 at 30 ft	NS lens 3600	WF lens 450
2500 HMI PAR at 30 ft	NS lens 2880	WF lens 247
4000 HMI Fresnel at 30 ft	2305	247
10k at 30 ft	2465	460
5k baby senior at 30 ft	655	110
PAR 64 at 30 ft	VNS lens 560	MF lens 150
2k junior at 20 ft	1000	130
1k baby at 20 ft	440	45
2k zip soft light at 10 ft		100
650 pepper at 10 ft	528	110
750 soft at 10 ft		30
200 mini at 10 ft	195	25
100 pepper at 10 ft	55	23

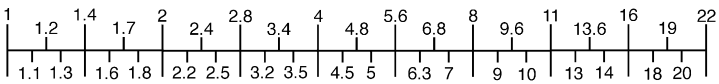

FIGURE 5.11

The actual numerical increments between f-stops.

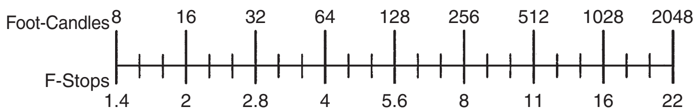

FIGURE 5.12

Comparison of foot-candles to f-stops with 320 ASA film.

Making allowance for this, the reading of a side-light can be accurately taken by turning the meter, splitting the angle toward the camera.

When reading the output of individual lights, some cinematographers replace the hemispherical collector with a flat disk collector. The flat disk reads only light coming from the front. The disk is also used when photographing flat artwork, such as a painting or frontlit titles.

Table 5.2 F-stop versus foot-candles for various film speeds

ASA	f/1.4	f/2	f/8	f/4	f/5.6	f/8	f/11
25	100	200	400	800	1600	3200	6400
50	50	100	200	400	800	1600	3200
64	40	80	160	320	640	1250	2500
100	25	50	100	5010	400	800	1600
125	20	40	80	160	320	640	1250
160	16	32	64	125	0500	500	1000
200	13	25	50	10	200	400	800
320	8	16	32	64	125	250	500
400	6.4	13	25	50	100	200	400
500	5	10	20	40	80	160	320

Notes: *Incident light in foot-candles. Frame rate: 24 fps. Exposure time: 1/50 s (180° shutter opening).*

When taking a reading, use your free hand to shade unwanted light off the photosphere. If you were reading the intensity of frontal lights, you would shade off any light coming from high back-lights. The facial tones are not affected by the light hitting the back of the hair and shoulders, and if you do not shade the meter from the backlights, the reading will be incorrect. Back light would be measured separately.

You can get an impression of the relative strengths of various lights—key and fill, for example—by shading the photosphere from one source, usually the key, and noting the change in the reading. You would use this technique to determine the *contrast ratio*.

A reading halfway between two numbers is called *a split*. For example, a 2.8/4 split would be halfway between f/2.8 and f/4. Increments between stops are also commonly expressed in thirds of a stop, so you might say "one-third stop closed from a 4" to indicate that the aperture is one-third of the way toward 5.6 (it is actually f4.5, see Figure 5.11).

For even smaller increments, a DP might specify "4 and a quarter" (which means a quarter stop closed down from f/4). Going the other way, the DP would say "a quarter stop open from 4." An even smaller increment would be a "heavy 4" or a "light 4." A heavy 4 would be just over a 4, a light 4 would be just under a 4 (opened up from a 4). Establish common terminology with the people you work with and use clear language. Double-check if you are not sure what someone means.

Reading the light meter is only part of the determining the aperture that will be set on the lens. The DP can use underexposure and overexposure selectively to affect the amount of apparent grain in the image as well as the contrast and the amount of detail the film will retain at the extremes of the film's latitude. The DP gives the lab specific instructions on how to handle these manipulations of the negative so that exposure on the final print or transfer is correct.

F-stops for the electrician

When setting a light, an increase of one stop means doubling the light level. The gaffer might tell the electrician to "remove a double," "spot it in a double's worth," or "move the light in one stop closer." An experienced electrician can approximate this by eye.

Contrast, latitude, and the Tonal Value

Contrast ratios

As a rule, the exposure is set for the key side of an actor's face (this is a rule DPs often break; but we will get to that in a minute). The darkness of the fill side greatly influences the emotional tone of the image. The *contrast ratio* quantifies the difference in their brightness. To determine the contrast ratio, compare the light on the key side, which is key plus fill, to the shadow side, which is fill alone:

key + fill: fill alone

If key plus fill reads 120 FC and fill alone reads 60 FC, the contrast ratio is 120:60, or 2:1. A 2:1 ratio has a one-stop difference between key plus fill and fill alone. A 2:1 ratio is relatively flat, a typical ratio for ordinary television productions. It provides modeling while remaining bright and void of noticeably strong shadows. With a two-stop difference, or 4:1 ratio, the fill side is distinctly darker and paints a more dramatic, chiaroscuro style. For most normal situations, the contrast ratio is kept somewhere between 2:1 and 4:1. A three-stop difference, or 9:1 ratio, puts the fill side in near darkness, just barely leaving detail in the shadow areas. A bright, sunny day typically has about a 9:1 ratio, requiring the addition of fill light to lower the contrast ratio.

Contrast viewing glasses

A contrast viewing glass is a dark-tinted (ND) glass that typically hangs around the gaffer's or DP's neck on a lanyard, like a monocle. By viewing the scene through the glass, the gaffer can evaluate the relative values—highlights and shadow areas. The glass darkens the scene so that the highlights stand out clearly and shadow areas sink into exaggerated darkness. The glass helps evaluate whether a particular highlight is too bright or a shadow too dark. On the other hand, if nothing stands out when viewed through the contrast glass, the scene has gotten too flat and monotonic; you might want to reduce the fill level, flag or net light off the backgrounds, and find places to add highlights. Contrast glasses are available in various strengths, which are meant to approximate the contrast characteristics of different film stocks. The glass becomes ineffective when it is held to the eye long enough for the eye to adjust to it. Encircle the glass with your hand so that your hand forms a light-tight seal around your eye. Use the rest of your hand to shade the contrast glass from flare. You can also evaluate contrast without the aid of a contrast glass in the old-fashioned way, by squinting.

Gaffers also frequently use a contrast glass to check the aim of the lights. By positioning herself on the actors' marks, a gaffer can center the aim of the light fixtures (without blinding herself) by viewing each light through the dark glass. Similarly, a contrast glass can be used to view the movement of clouds in front of the sun on days with intermittent cloud cover. A "gaffer's glass" or "welding glass" is an even thicker glass, which should be used if you are looking directly at the sun. Another way to check whether clouds are about to move in front of the sun is to take off your sunglasses and view the sun's reflection in them.

The zone system

The human eye can see detail in a much wider range of contrast than film emulsion. Although a person looking at a scene may see detail in every shadow and every highlight, on film, anything too dark or too bright relative to the chosen exposure starts to lose definition as it approaches the extremes of the film's latitude. Details disappear into obscurity, and objects become either more and more bleached out or increasingly lost in blackness.

It is helpful to think of the tones in a black-and-white picture. Between pure black and pure white lies a range of *values*, shades of gray that define the picture. The goal in choosing the exposure and illuminating the scene is to place those values so that they will be rendered on film as the cinematographer envisions them.

Ansel Adams, the American still photographer, invented the zone system in 1941 (with Fred Archer) as a tool for understanding how the values in a scene will be rendered on film. With the black-and-white still film and printing process he was using, he could create 11 zones, as shown in Figure 5.13. Zone 0 is pure black and zone X is pure white. Each zone is one stop lighter than the last.

The range of brightness and darkness in which film emulsion can capture an image is known as its *dynamic range*. The dynamic range is the range from zone I to zone IX. Adams referred to the range between zone II and zone VIII as the *textural range*. In this range, texture is visible, and one can recognize substance to the form. Each film emulsion or video sensor has its own dynamic

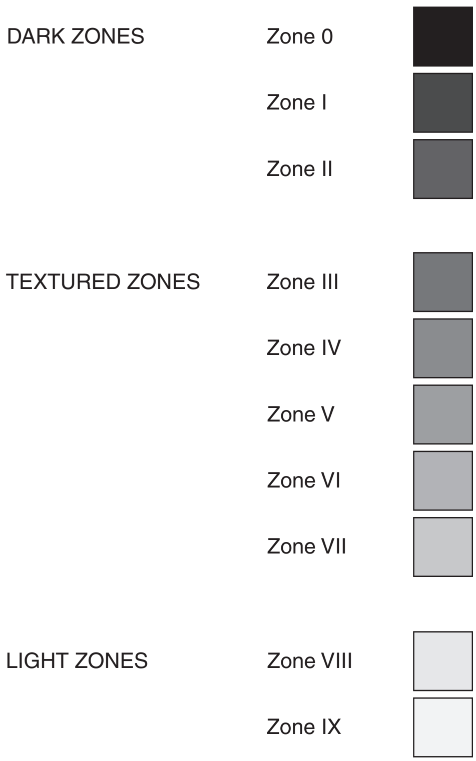

FIGURE 5.13

The 11 values of the zone system. Zone X is pure white. It is not shown here.

(From Chris Johnson, The Practical Zone System: A Simple Guide to Photographic Control, *Boston: Focal Press, 1986, p. 31. Reproduced with permission of Focal Press.)*

range characteristics. Cinematographers must therefore be familiar with the response of different film stocks or video sensors. Reversal film stocks and video cameras have less dynamic range. In cinematography, the range from zone III to zone VII typically represents the textural range.

Zone V, middle gray, is a very important value for determining exposure. Middle gray is 18% reflective and commonly called 18% *gray*. An incident light meter works by defining this midpoint in the latitude of the film. It gives an exposure reading that will make a middle-gray object appear middle gray on screen. When you define the exposure of middle gray, all the other values fall into place (to the extent of the film's latitude). On the outer edges of the exposure latitude, the image begins to lose detail and textured areas become less defined until, at the extremes of the scale, in zones I and IX, no detail is visible and, in zones 0 and X, only pure black and pure white are seen. Ansel Adams described the appearance of each zone on film something like this:

- **0** Total black. With a film stock that holds blacks well, the blacks on the edge of the frame merge with the black curtains surrounding the screen.
- **I.** Threshold of tonality but with no texture.
- **II.** First suggestion of texture. Deep shadows represent the darkest part of the frame that still shows some slight detail.
- **III.** Average dark materials and low values, showing adequate texture.
- **IV.** Average dark foliage, dark stone, or sun shadow. Normal shadow value for white skin in sunlight.
- **V.** Middle gray (18% reflectance). Clear northern sky near sea level, dark skin, gray stone, average weathered wood.
- **VI.** Average white skin value in sunlight or artificial light. Light stone, shadows on snow, and sunlit landscapes.
- **VII.** Very light skin, light gray objects, average snow with acute side lighting.
- **VIII.** Whites with texture and delicate values. Textured snow, highlights on white skin.
- **IX.** White without texture, approaching pure white. Snow in flat sunlight.
- **X.** Pure white. Spectral reflections, such as sun glints or a bare lightbulb.

The way the cinematographer lights the set and sets the exposure determines the various values of the scene. Suppose that the exposure outside a room with windows is five stops brighter than inside the room. If the aperture is set for the interior exposure, all details in the exterior portion of the image will fall into zone X and be completely bleached out; the edges of the windows will likely get "blown out," with soft fringes around them. A compromise somewhere between the exterior and the interior exposures is not much better; the interior will still be very dark and muddy (zone III) and the exterior will be hot (zone VIII). The lighting must bring the outside and the inside exposures closer together.

To look natural, the exterior should be brighter than the interior, but by two or two and a half stops, not by five. To close the gap, you could reduce the exterior exposure two stops by gelling the windows with 0.6 neutral-density gel; you could light the inside, bringing it up to a level that is two stops less than the outside exposure; or you could combine these techniques.

Previously, I said that as a rule, the key side of the actor's face is set *at exposure*; in other words, you would take a light reading of the key side (key plus fill) and set that exposure on the lens. In reality, a much more expressive image is created by carefully placing the values of the face in

response to the natural sources within the scene and the dramatic feeling of the scene. In fact, a creative cinematographer will tell you, as a rule, *never* place the key side at exposure. For example, overexposing the key side by one stop while underexposing the fill side by one and a half stops gives a greater sense of light entering a space (through a window for example). In a dark scene, the DP might underexpose the key side of the face by one stop and let the fill side fall into near darkness, three stops underexposed. The exposures on the actors' faces are balanced to some extent by other values in the image. If the scene is largely underexposed but some bright sources are within the frame, there is a reference point for the viewer's eye. The values of backgrounds, practical lights, windows, and so on can be manipulated to place their relative intensity in the zone desired. A spot meter can be used to measure and compare reflective values, but with practice, one mostly balances levels by eye.

Negative film stocks tend to have greater latitude in overexposure than they do in underexposure. As a general rule, a neutral-gray object can be overexposed by as much as four stops and underexposed by up to about three stops before it becomes lost, either washed out or lost in dark shadow.

Reversal film stocks have the opposite response: they have greater latitude in underexposure and lose definition faster in overexposure. Reversal stocks tend to be more contrasty and have less latitude in general than negative stocks. Similarly, video cameras have narrow latitude: typically, detail is well rendered only within a four- or five-stop range.

Spot meters

A spot meter (Figure 5.14) is a reflected light meter with a very narrow field of acceptance (less than 2°). An incident meter reads the amount of light hitting the light meter; a reflected meter reads the amount of light reflected back from the subject.

The reading depends on the reflectance of the object as well as the amount of light. From behind the camera, the DP or gaffer can sight through the meter and pick out any spot in the scene to measure, taking readings of various areas of the scene, to compare the exact values of face tones, highlights, and shadows.

Digital spot meters typically display readings in either f-stops or in EV units. Some meters display readings only in EV units; the corresponding f-stop is found using the conversion dial on the meter. Table 5.3 shows how spot meter readings correspond to reflectance. The f-stops listed down the left side of the table represent the aperture setting on the camera lens. The zones across the top of the table indicate the actual reflectance, which corresponds to spot meter readings taken off various areas of the composition.

EV units are handy, because they put reflectance value on a linear scale in one-stop increments. Each EV number represents a one-stop difference in value from the last. It eliminates the mental gymnastics involved in counting on the f-stop scale. For example, if a skin tone reads f/8, and a highlight reads f/45, how many stops brighter is the highlight? Before you start counting on your fingers, let's ask the same question in EV: The skin tone reads EV 10, the highlight EV 15; it's easy, the difference is five stops. You can even set the ASA on the spot meter so that EV 5 represents the f-stop on the lens. By so doing, you calibrate the meter to read out in zones: EV 0–10 equal zones 0–X.

FIGURE 5.14

Sekonic L-608 Cine Super Zoom Master digital spot meter. A parallax-free zoom spot meter (1–4 degrees) with a retractable incident lumisphere for incident light readings. Frame rates from 1 to 1000 fps can be set on the meter. Shutter angles from 5° to 270° and filter compensation can also be set on the meter. Reads in f-stops (f/0.5–f/45), foot-candles (0.12–180,000 FC), lux, Cd/m^2, foot-lamberts, and EV (exposure value; incident and reflected). The meter notes and remembers readings using nine memory banks, handy for evaluating contrast.

(Courtesy Sekonic.)

Table 5.3 Spot meter readings, reflectance, and f-stops

Aperture setting: f-stop	0	I	II	III	IV	V	VI	VII	VIII	IX	X
1.0	–	–	–	0.5	0.7	1.0	1.4	2.0	2.8	4	>5.6
1.4	–	–	0.5	0.7	1.0	1.4	2.0	2.8	4	5.6	>8
2.0	–	0.5	0.7	1.0	1.4	2.0	2.8	4	5.6	8	>11
2.8	<0.5	0.7	1.0	1.4	2.0	2.8	4	5.6	8	11	>16
4	<0.7	1.0	1.4	2.0	2.8	4	5.6	8	11	16	>22
5.6	<1.0	1.4	2.0	2.8	4	5.6	8	11	16	22	>32
8	<1.4	2.0	2.8	4	5.6	8	11	16	22	32	>44
11	<2.0	2.8	4	5.6	8	11	16	22	32	44	>64
16	<2.8	4	5.6	8	11	16	22	32	44	64	>88
22	<4.0	5.6	8	11	16	22	32	44	64	88	>128

A great many cinematographers rely almost exclusively on a spot meter for light readings. Knowing that the reflectance of average Caucasian skin is about zone VI and one stop lighter than 18% gray (zone V), the DP can base the f-stop on a spot reading taken off an actor's face (or his own fist held out in front of the meter to provide a flesh tone). The DP makes the necessary one-stop compensation mentally.

When reading the reflectance of Caucasian skin, the reading will be a half to one and a half stops brighter than the setting on the lens. Brown and olive skin falls around zone V, and dark brown and black skin values fall between zones II and IV. When lighting and exposing black skin, the shininess of the skin plays a larger role in determining the light value than with lighter skin. Reflective glints off black skin may range up into zone VI or higher. There is a tremendous range of tonal values in human skin that the cinematographer observes and takes into account. You can find out the exact reflectance of a particular actor by comparing the reading of the face to that of a gray card or one's own hand.

A spot meter is particularly handy for measuring naturally luminescent sources, such as television screens, table lamps, illuminated signs, stained glass windows, neon lights, or the sky during sunrise and sunset. It is also handy for getting readings on objects that are inaccessible or far away.

Light level

A single parameter that greatly affects all a gaffer's major decisions is the amount of light the DP wants to film a scene. One DP I worked with always shoots ASA 50 film at a f/4 or f/5.6, indoors or out, requiring a light level of 400–600 foot-candles. To do this requires many large HMI units, heavy 4/0 cable, many large power plants, and lots of hard-working hands. Another DP shoots ASA 500 film with a very low f-stop, requiring only about 32 foot-candles of illumination. Sometimes the biggest light needed is a 2k or baby and the biggest cable is banded #2 cable. The choice of light level affects everything: what lights to order, the power requirements, and the time and personnel needed.

Film speed

A DP's choice of film stock depends on many factors, including the subject matter of the film, the director's ideas about how it should look, the types of locations, the need for matching with other stocks (matte work and opticals), and personal style of lighting and preferences about grain and color.

As illustrated in the preceding examples, the *speed* of the film, or ISO (also termed ASA or EI), is the primary determinant of light level. A high-speed film emulsion is very light-sensitive and requires little light to gain an exposure. Slower film stocks require more light, but have less apparent grain, finer resolution, and more deeply saturated colors.

The choice of film stock also affects the look of the lighting. If a slow film stock is used in an interior scene, a fairly drastic increase in light level is required, virtually replacing all natural light with brighter artificial sources. The large lights must very often be hung above the set, giving limited realistic lighting angles. Faster film stocks and lenses enable a more subdued lighting approach, with fewer and smaller artificial lights brought to bear. The small lights are easier to hide, allowing more realistic angles for the light. The cinematographer can use existing light to a greater extent.

Optimizing lens characteristics

Some lenses have the greatest clarity and definition in the middle of the f-stop scale, between f/4 and f/8. Some loss of quality occurs at the ends of the scale. For this reason, sometimes cinematographers ask for sufficient foot-candles to work in the center of the scale. Also, because lens characteristics change very slightly at different f-stops and for simplicity of lighting, DPs often prefer to shoot all the shots for a particular sequence at more or less the same f-stop.

Depth of field

An important tool in the cinematographer's bag is selective focus. Depth of field is the amount of depth that appears in focus. As the iris is opened up to lower f-stops, the depth of field decreases. Depth of field also decreases with an increase in the focal length and a decrease in the subject's distance to the lens.

Depth of field is directly proportional to the f-stop. The DP who wants shallow focus with a given lens needs to use a low f-stop (f/2 or f/2.8) and, therefore, low light levels or filters must be used. Lots of depth requires a higher f-stop, necessitating higher light levels. Thus, the depth of field also affects the size and type of lighting fixtures used to light the scene.

Varying exposure time

When the camera is operated at high speed for slow-motion photography, the exposure time is decreased and the aperture must be opened up to compensate. For example, when filming a car stunt at night with multiple cameras, the working light level must be high enough to accommodate a lower f-stop setting on high-speed cameras. An f/4 (uncompensated) would force a camera running at 120 fps to expose at under an f/2. This could be accomplished with the use of super-speed lenses, which open up to about f/1.4, but could not be accomplished with many standard lenses, which typically open up to between f/2 and f/2.8, or many zoom and telephoto lenses, which are slower still. Similarly, if the shutter angle is reduced, the exposure time is reduced.

When shutter speed or shutter angle is not standard, everyone must be very clear when giving f-stops as to whether the f-stop compensation has been taken into account. When giving the f-stop, you would say it is an "f/4 on the lens," meaning that the compensation has been taken into account. If not, you should say you are giving an uncompensated reading, which DPs sometimes call a "base" stop. This can be helpful when the cinematographer is using multiple camera crews and the cameras are using different amounts of ND filtration. The DP calls the base stop, and the camera assistants adjust to compensate for their particular filtration.

CHAPTER

6 Manipulating light: Tools, techniques, and the behavior of light

I can't stand a naked light bulb any more than I can a rude remark or vulgar action.

—Tennessee Williams, *A Streetcar Named Desire*

In our work in motion picture and television, we can identify five properties of light that we manipulate to create compelling images. They are: color, brightness, shape (or pattern), quality of light (hard or soft), and movement. The techniques used to manipulate and control these five properties represent the central knowledge required of a lighting technician working on set. Mastery of the principles that govern the properties of light is the very core of the expertise a director of photography and gaffer bring to a project. Our understanding of these principles deepens with experience, but it begins with the essentials discussed in this chapter.

COLOR

The lighting crew has two goals when it comes to color. The first is the technical process of matching the white balance of the light sources to each other and to the rated color balance of the film stock or video camera. The second is aesthetic: introducing color into the light, for effect, or to simulate real sources, such as skylight, late afternoon sun, sodium vapor, firelight, neon light, blue moonlight, and so on. As discussed in Chapter 5, subtle color contrast is one way the DP can help delineate the layers within an image and create lighting that feels true to life and less artificial.

White balance

Light is a narrow band within the electromagnetic spectrum, as shown in Figure 6.1. Wavelengths from 380 to 760 nanometers (nm) are detectable to the human eye as visible light. The color of a light source is determined by the intensity of the various wavelengths that make up the light. When the full range of wavelengths is combined, the result is said to be "white" light. Nonetheless, all "white" light has colored tint to it depending on its particular balance of wavelengths. Because the human eye adapts to its surroundings, shifts in balance are not always apparent to the human eye unless one light source is compared directly with another. An incandescent light produces light that is orange compared to an HMI, which is stronger on the blue end. Commercial fluorescent tubes produce light that has strong spikes at several places in the spectrum, which often give it a green hue.

Unlike the human eye, a film stock or video sensor cannot adjust to these variations. Color rendition is always relative to the white balance of the film stock, or video processor. White balance can be thought of in two dimensions. On one axis are the range of colors between blue and orange;

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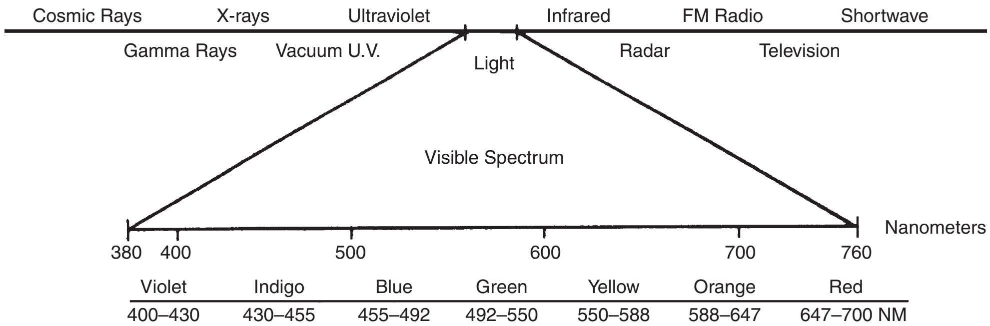

FIGURE 6.1

The color spectrum is a narrow band within the electromagnetic spectrum. Individual colors of light within the visible spectrum combine to make "white light."

this is known as *color temperature*. On the other axis are the range of colors between magenta and green. Let's look first at color temperature, and then at the color space around this locus.

Kelvin color-temperature scale

The color makeup of any source that has a continuous spectrum, such as an incandescent light, can be measured on the color-temperature scale and quantified in degrees Kelvin. Figure 6.2 shows how the distributions of wavelengths differ for sources of different color temperatures.

You may be wondering why the Kelvin scale (a temperature scale) is used to quantify color balance. In order to give us a fixed reference point, scientists decided to compare the color make up of any source to that of a theoretical "perfect black body radiator" when it is heated. The idea is that light is emitted when a substance is heated. How much it is heated determines the color makeup of the light. When heated a little, it glows red. Heated more, it becomes orange, then yellow, and then gradually less yellow and more pale blue, and finally brilliant blue. So the color makeup of a tungsten light is the same as that emitted by a "perfect black body radiator" heated to 3200 K. The higher the Kelvin reading, the bluer the light. Natural daylight is a combination of skylight, which is very blue (around 10,000 K), and sunlight, which changes with the time of day. Daylight film emulsions use 5600 K as the daylight color reference. Table 6.1 gives the color temperatures for a wide variety of light sources. It also lists the corresponding micro reciprocal degrees (MIRED) values. MIRED values are used to calculate color temperature shifts, as explained shortly.

Color space

The CIE 1931 chromaticity diagram[1] (Figure 6.3) represents the entire gamut of human visual perception—all the wavelengths visible to the human eye. The wavelengths of the visible spectrum are quantified in nanometers (nm). The wavelengths are shown around the outside curved edge of the

[1]The International Commission on Illumination (CIE) first defined human perception of color mathematically in a 1931 study. This definition is known as the CIE 1931 XYZ color space. Although many subsequent advancements have been made, the CIE 1931 diagram still serves as a very useful model for understanding many fundamental aspects of color.

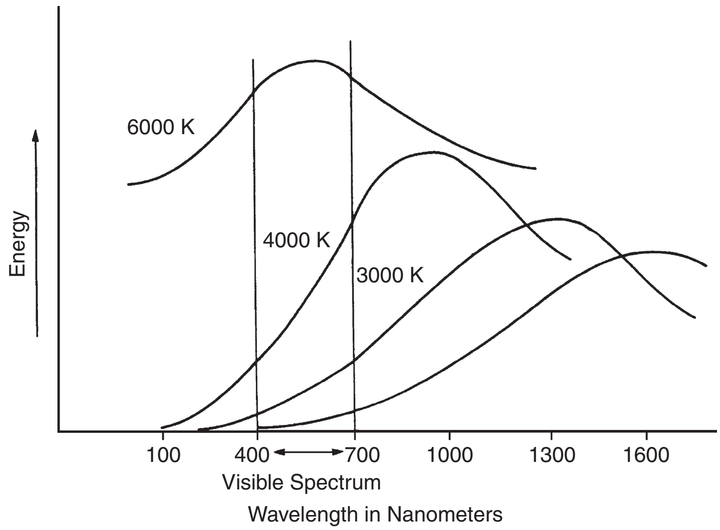

FIGURE 6.2

Distribution of energy for various color temperatures across the visible spectrum. Note the distribution of energy in a tungsten source (3200 K) favors the red end of the spectrum, while in a daylight source (5600 K), the curve slopes downward at the red end and the distribution of energy is more even over the visible spectrum.

Table 6.1 Color temperature of various sources

Source	Kelvin	MIREDs
Match or candle flame	1900	526
Dawn or dusk	2000-2500	500
Household bulb	2800-2900	357-345
Tungsten halogen bulbs	3200	312
Photo flood bulbs	3400	294
1 hour after sunrise	3500	286
Late afternoon sunlight	4500	233
Blue glass photoflood bulb	4800	208
3200 K lamps with dichroic filter	4800-5000	208-200
FAY lamps	5000	200
Summer sunlight	5500-5700	182
White flame carbon arc light with Y-1 filter	5700	175
HMI light	5600 or 6000	179 or 167
Sunlight with blue/white sky	6500	154
Summer shade	7000	141
Overcast sky	7000	141
Color television	9300	108
Skylight	10,000-20,000	100

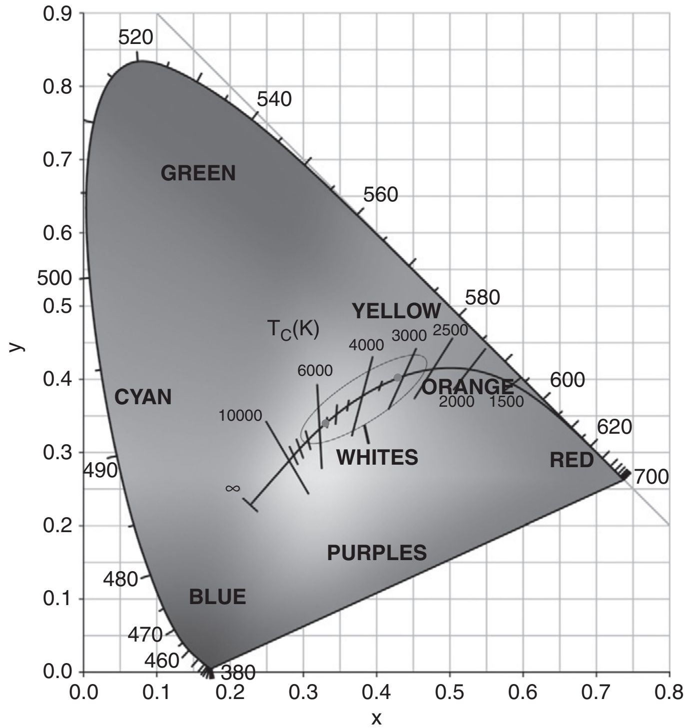

FIGURE 6.3

The CIE 1931 Chromaticity Diagram shows the gamut of human visual perception. The Plankian locus describes the colors of light possible from a black-body radiator, such as the sun, or an incandescent lightbulb.

diagram: moving from the bottom-left corner clockwise, it starts with violet and deep indigo blue (380-455nm), blue (430-455nm), then cyan, fades to green around the top of the diagram (520nm). Along the right side of the triangle green fades into yellow (500-588nm), orange (588-647nm) and finally to red at the bottom-right corner (700nm). Along the bottom of the diagram are the hues created by mixing red and blue light: lavender, purple, and violet. The *line of purples*, as they are called, can be made only by combining colors; they do not exist as single wavelengths. The outside edges of the diagram represent the most saturated pure colors possible. As you move into the center of the diagram, the colors become less and less saturated, and the center portion represents white light—this is the portion that we are interested in for this discussion. The curved line leading from orange to blue is called the *Plankian locus*; the color makeup of black-body sources—light sources that have a continuous spectrum—will be represented by a point that is somewhere on this line.

Along this locus, we find a point at 3200 K that will be represented as pure white on tungsten-balanced film or 3200 K balanced video camera. We find another point at 5600 K, which represents the color of light that will be represented as pure white when using a daylight-balanced film stock or video camera. Any incandescent light will fall somewhere on the Plankian locus. If you were to dim an incandescent light, the color temperature would decrease, and the color would move toward

orange, but it would remain on the Plankian locus. When you apply CTO or CTB gel (color temperature orange or color temperature blue) to a light source, the resulting light is shifted up or down the Plankian locus. The gels redistribute the spectrum by reducing the intensity of selected wavelengths in a given source. Full CTO must be applied to daylight sources to match with tungsten film. Full CTB must be applied to incandescent sources to match to daylight film. In film and television lighting, we often like to use tints that shift the color one direction or another along this locus using increments of half and quarter CTO and CTB. This type of shift appears natural, perhaps because we experience it in everyday life.

Correlated Color Temperature

The color makeup of sources that do not have a continuous spectrum (HMIs, fluorescents and LEDs) can also be given a Kelvin rating, termed the *correlated color temperature* (CCT). The correlated color temperature is the Kelvin rating that—to human color perception—most closely matches the color makeup of the source. You'll notice that above the Plankian locus the color of the light moves toward green, and below the locus it moves toward pink or magenta. These color points are not on the color temperature scale, but they can be given a correlated color temperature. The hash marks that cross the Plankian line at an angle connect points that have the same correlated color temperature. "Plus green" and "minus green" gels are used to shift the color along this axis. A magenta gel can be applied to a green fluorescent to neutralize the green appearance. Conversely, a green gel might be applied to a tungsten light to match it to a greenish fluorescent. (If the correction gel were not used, then when the colorist attempts to reduce the green appearance in the telecine or at the lab, the tungsten light will turn pink.)

The CCT gives the effective color temperature of the source to the human eye when the spikes in the color curve are combined together. Fluorescent lights come in various color temperatures. Daylight tubes are designed to light spaces that have supplementary daylight, such as offices with large windows. The light is color balanced toward the blue end of the spectrum (5000–6500 K) to blend with the window light. Warm lights, which have a color temperature closer to that of household bulbs (3000 K), are for use in enclosed spaces where supplementary light comes from table lamps and wall sconces.

Color Rendering

In addition to the correlated color temperature, manufacturers of fluorescent, metal halide and LED lamps and light fixtures typically provide an indication of the lamps ability to render the full spectrum of colors accurately. This data can give the gaffer valuable information about the general performance characteristics of a given source, however comparing the CRI values of two sources with relatively good CRIs can be misleading for reasons we shall discuss shortly.

The *color rendering index* (CRI) is a rating, from 1 to 100, meant to express the accuracy of a light's rendering of color when compared with a perfect reference source (daylight is a perfect 100). A rating above 90 is considered accurate color rendition for photography. With a CRI above 80, the eye can still make accurate color judgments and the color rendering is termed *acceptable*. Between 60 and 80 color rendering is *moderate*. Below 60 color rendering is *poor* or *distorted*.

The CRI index developed in the mid-twentieth century when fluorescent and metal halide light sources started to proliferate. Color scientists became interested in quantifying the ability of artificial lights to reproduce the full spectrum of colors. The CRI of a lamp is determined by illuminating

eight standard test colors with the artificial light and comparing it mathematically to the same test colors illuminated with an ideal source. HMI and LED manufacturers sometimes express frustration that a lamp with a pretty good spectrum of color, but having peaks and valleys in its spectrum, may not hit the eight test colors dead on, and can end up with a lower CRI than another lamp that has no greater color rendering on average, but happens to represent the eight test colors well. Scientists have developed more accurate modern methods for quantifying color rendering, but lamp manufacturers still use CRI data, and none of the improved methods have yet been universally implemented to replace it.

On location, you will run into *standard* fluorescents and *full-spectrum (high-CRI)* fluorescents. Table B.2 lists specifications for various types of fluorescent tubes. A high CRI tells you that the tube has a nearly complete spectrum of light frequencies and is therefore capable of rendering colors well; however, they often have a strong green spike and require color correction, which typically involves a combination of magenta and CTO gels. The amount of magenta filtering varies and does not necessarily correspond to CRI rating. For example, the Optima 32 (CRI 82) has excellent color rendering on film and requires little or no color correction. A Chroma 50 (CRI 92) shows a strong green spike on film that must be removed with half minus-green gel. (Both Chroma 50s and Optima 32s were manufactured by Durotest, which is now out of business.)

A low CRI rating indicates the lamp emits a very limited spectrum of light and is incapable of rendering all colors. The color rendering of fluorescent tubes in office buildings, warehouses, factories, and commercial buildings will depend on the lamps being used. If the tubes have low CRI ratings they should be replaced with better tubes for filming.

Color chips and gray scale

When the film laboratory makes a print or video transfer from a developed negative film, the timer or colorist adjusts the exposure and colors of the print to make them look natural (or however the DP instructs). A DP who introduces colors into the lighting must take steps to prevent the colorist from removing the color in the transfer or print. To give the lab a reference at the beginning of each film roll, the camera assistant films about 10 seconds of color chips or gray scale under a selected color balance of light. The *chip chart*, or color chart, has a set of standard colors or a scale of gray tones from white to black from which the colorist can work. The chip chart must be filmed under light that is exactly the proper color temperature. When a DP wants to render colors normally, he uses a perfect "white" light for the chip chart. A light that has been checked beforehand with a color temperature meter should be standing by for chip chart shots. When filming the chip chart, no other light should fall on the chart. You may need to turn off or block lights momentarily to prevent extraneous light from discoloring the chip chart. It is also helpful to the colorist to see skin tone with the chip chart, and even to see the scene in the background with all its "nonstandard" color.

A DP who wants the lab (or telecine house) to give the film print (or video transfer) an overall color cast might modify the color of the light hitting the gray scale. For example, for the lab to warm up the dailies (make them more golden and yellow), the DP might film the gray scale with ¼ or ½ CTB on the chart light. When the lab puts in the color settings to compensate for the blue chart, it will add yellow, which will show in the footage.

When working with multiple video cameras, the engineer puts up a chip chart in front of each camera before beginning shooting and electronically adjusts the signal from each camera so that they match each other and give proper color rendition.

Color-temperature meter

A color-temperature meter gives a Kelvin reading, and a reading of the green/magenta shift of the light hitting the cell of the meter. It is important to realize that, although a cinematographer's color meter, is calibrated at the factory, the readings of two identical meters will often differ. This type of color meter is accurate for comparing the color temperatures of several continuous light sources, but no Kelvin reading should be taken as an absolute value. When more than one meter is being used to take readings on the set, the meters should be checked side by side under the same light to determine the variation between them. Common color meters, like the Minolta II or Minolta III F, make their calculation of the color temperature based on an assumption that the light source has a continuous spectrum. The meter extrapolates the color temperature from the ratio between blue and red in the source. This is an accurate method when reading incandescent sources; however, color readings of LEDs and HMIs have been shown to be misleading for both CCT and green/magenta shift. A tri-stimulus meter (such as the Sekonic C-500 (Figure 6.4), the Gossen Colormaster 3F, or the Minolta CL-200) is a much more sophisticated (and expensive) instrument, capable of greater accuracy.

FIGURE 6.4

The Sekonic Prodigi Color C-500 Color Meter incorporates four color sensors: one green, one blue, and two red sensors—one that emulates film response, and one that emulates digital and human visual response. The meter reads color temperature (Kelvin degrees) and provides LB (orange/blue correction in MIREDs) and CC (green/magenta color compensation CC values, and the filter number needed to correct the source). The meter also reads luminance in lux and foot-candles.

(Courtesy Sekonic.)

Light-balancing scale: Orange/blue shifts

Most color meters automatically calculate the MIRED shift from the Kelvin reading. This shift is generally referred to as the *light-balancing* (LB) index number. This number indicates the amount of amber or blue correction gel needed to match the source to the color temperature of the film stock. To use the LB scale, the color balance of the film stock must be preset on the meter—film type B, 3200 K; film type A, 3400 K (which is used for some still film stocks); or film type D (daylight), 5500 K. Many meters also have a manual mode that allows you to enter any target Kelvin temperature. The manual mode comes in handy when the cinematographer needs to have all the lights balanced to a nonstandard Kelvin rating. Many color meters also give the Kodak filter number and the amount of exposure change corresponding to the LB reading. Kodak filters are used in the camera in situations where an overall color correction is needed. For example, when filming a scene in which the practical lamps are unavoidably yellow, the DP can match the movie lights to the practicals by adding ¼ CTO gel, then, to the degree desired, cancel out the yellow cast with a blue filter on the lens (or filter slot), (however this is more commonly accomplished in the lab or telecine) or with the white balance function on a video camera.

Color-compensation scale: Green/magenta shifts

The color temperature meter also gives a *color compensation* (CC) reading that indicates the amount of green or magenta gel needed to correct a source to appear white on film. Such a correction is typically required by commercial fluorescent lights and sometimes HMIs and LEDs. A CC reading of 30 M indicates that full minus green (M is for magenta) is necessary. A reading of 15 M requires half minus green. Table I.9 lists green/magenta correction gels and the corresponding color meter readings.

Color-correction gels

Correction gels come in densities of full, half, quarter, and eighth correction. Correction gel typically comes in rolls 48 or 54 in. wide and 22 or 25 ft. long. When gel is cut from the roll, the cut pieces should be labeled (F [full], H [half], Q [quarter], or E [eighth]) and organized by size and color.

As we have said, CTO gels are orange; they "warm up" a light source. The 85 gel corrects sunlight and HMI sources to 3200 K. Full CTO or extra CTO correct cooler skylight to tungsten, or 5500 K sources to a warm yellow 2800 K.

Conversely full CTB gel corrects a tungsten source to daylight balance. However, it is impractical to use fully corrected tungsten lights when shooting with daylight-balanced film. Tungsten lights are very weak on the blue end of the spectrum. Full CTB reduces light transmission by 85%, or about two stops. (The gel has to absorb 85% of the energy from the light; consequently, the hot-burning lights also burn out blue gel very quickly.) When working with daylight-balance, tungsten sources are typically avoided. HMI and fluorescent fixtures provide daylight-balanced light that is cleaner, brighter, cooler, and a more efficient use of power.

Eighth, quarter, and half CTO and CTB gels are often used to warm up or cool down a source. Subtle tints can enhance the colors of the actors' faces, their clothes, and their surroundings, and can give the scene. A fire light might use half, full, or even double CTO. A sunset or dawn scene might be filmed with a full CTO on the lights to simulate the golden light of the low sun. Quarter CTO and quarter CTS (color temperature straw) are used for simulating a warm interior source such

as practical lamp, candle or oil lantern. Commonly a ¼ or ½ CTB is used when the DP desires a cool blue look to a particular light source. An exterior winter scene shot on a sound stage might use soft lights gelled with a ½ or ¾ CTB to cool the scene. Skylight entering a window, twilight, or moonlight also call for a cooler light.

When using HMI lights in a tungsten-balanced scene, the amount of blue tint in the light is controlled by the amount of CTO correction applied to the light. When a slightly cool light is desired, a half CTO is applied, bringing the 5600-K source down to about 3800 K. By the same token, when a daylight-balanced scene requires a warm source it is reasonable to use a tungsten light gelled ½ blue.

Gelling windows

When the outside of the window is accessible, gel can be stapled or taped over the outside window frame, which hides the gel more easily. When stapling gel, apply a square of gaffer's tape to the gel and staple through the tape to prevent the gel from ripping. The key to gelling windows is to keep the gel tight and free of wrinkles. CTO correction is also available in 4-ft × 8-ft acrylic sheets. Using acrylic sheets avoids the problems of wrinkles, movement, and noise that gel makes.

With a very light dusting of spray adhesive (Spray 77), you can stick gel directly onto a window or acrylic sheet. Press bubbles and wrinkles out to the edges with a duvetyn-covered block of wood. If gelling windows promises to become an everyday process on a particular location, an elegant system is to cut acrylic inserts to fit the windows, then add neutral-density (ND) and CTO gel (using the spray adhesive technique) as needed to suit the light conditions and time of day. Move the inserts around from shot to shot depending on the camera angle.

You can also use snot tape (3M transfer tape) or secure the gel by carefully taping around the edge of it with tape that matches the color of the window frame. Another fast method is to spray water on the windows and apply the gel with a squeegee. This method will not last all day, but it saves so much time that it doesn't matter if it must be redone.

Neutral-density and combination neutral-density/CTO correction gels

ND gel is gray; it decreases the intensity of a light source without altering color. Neutral density gel is also available in combination with CTO, for gelling windows.

Type	Light reduction
ND 0.3	1 stop
ND 0.6	2 stops
ND 0.9	3 stops
ND 1.2	4 stops

A combination of CTO/ND gels and acrylic sheets is commonly used to reduce the brightness of windows.

Using MIRED units to calculate color shifts

One can make calculations of color temperature shift using values called *MIREDs.*

Although the Kelvin scale is useful for defining the color temperature of a source, it is an awkward scale to use when quantifying the effect of a color correction gel or filter. You cannot simply

Table 6.2 Color temperature resulting from applying common color-correction gels

Gel applied	Daylight source, 5600 K	Tungsten source, 2900 K	Tungsten source, 3200 K
⅛ CTO	4900 K	2700 K	2950 K
¼ CTO	4100 K	2450 K	2650 K
½ CTO	3450 K	2200 K	2350 K
Full CTO	2950 K	2000 K	2100 K
⅛ CTB	6200 K	3050 K	3400 K
¼ CTB	7000 K	3250 K	3600 K
½ CTB	9900 K	3750 K	4250 K
Full CTB	23,800 K	4800 K	5700 K

Note*: Results are rounded to the nearest 50°. Exact results vary depending on the brand of gel and exact color temperature of source.*

state that a particular gel creates a 200-K shift. The Kelvin shift of a given correction filter depends on the color temperature of the *light source*. A blue gel that alters a tungsten source 200 K (from 3200 to 3400 K) alters a daylight source 650 K (from 5600 to 6250 K).

These calculations have been made for you in Table 6.2 and in Appendix I. Table 6.1 shows the MIRED value of a variety of sources. Table 6.2 shows the color temperature resulting from applying common color correction gels to different light sources. Tables I.1–I.3 tell you what gel to use to get from any color temperature to any other color temperature. Table I.4 lists the MIRED value for any Kelvin number from 2000 to 9900 K. Tables I.5–I.7 list the color shift in MIREDs of color correction gels of various manufacturers. When gel manufacturers quantify the effect of color correction gel, they use MIRED units rather than degrees Kelvin. MIREDs provide a linear scale on which to calculate the shift of a given gel on any source.

The MIRED value is equal to 1 million divided by the Kelvin color temperature:

$$\frac{1\,\text{million}}{\text{K}} = \text{MIRED value}$$

The MIRED shift of a particular gel needed to get from any Kelvin temperature (K_1) to any other Kelvin temperature (K_2) is as follows:

$$\text{MIRED shift} = \frac{1\,\text{million}}{K_1} - \frac{1\,\text{million}}{K_2}$$

Note that tungsten color temperature is 312 MIREDs, and daylight is about 179 MIREDs. To correct a daylight source to tungsten, a shift of +133 MIREDs is required. To correct a tungsten source to daylight, a shift of −133 MIREDs is required.

Dichroic filters and reflectors

The most common type of dichroic filter is a coated silver reflector or glass filter that fits onto some open-face lights to make a tungsten-to-daylight conversion (3200-5600 K). This process reduces

light output by about two stops. The filter or reflector is easily identified by its iridescent appearance, like gasoline in a water puddle.

A dichroic filter works by optically canceling out certain wavelengths of light. It does not involve dyes or pigment but rather reflects selected wavelengths of light by the thickness of a chemical coating on the glass. The thickness of the coating is one-quarter of the wavelength of the selected color's chromatic opposite. Manufacturers can custom make dichroic glass filters in practically any color. Their advantage over gel is that they never fade. They are ideal for long-term installations, where the cost and trouble of replacing faded gel every week outweighs the initial expense of buying glass filters. The trick to them is that light has to pass through the filter exactly perpendicular to the plane of the glass or the color will start to vary. For some lights, a curved glass filter is necessary. Manufacturers include Rosco (Permacolor Glass Filters) and Automated Entertainment Manufacturing (HD Dichroic).

Before the dichroic filter came along, the MacBeth filter was used. It is simply a blue glass filter.

Green/magenta color correction

Green and magenta color correction gels were developed primarily to allow color matching between fluorescent lights and other sources. Table I.9 lists green and magenta correction gels and Kodak filter numbers and corresponding color meter readings that may be useful in this process.

There are three general approaches to matching the color temperatures of fluorescent lights, tungsten lights, HMIs, and daylight: (1) Match all the sources to daylight (5600 K), (2) match all the sources to tungsten (3200 K), or (3) match all the sources to fluorescent daylight (5600 K plus green). What works best depends on the situation. A loft with huge windows along the walls would not be a good candidate for a window gelling solution: better to change out the fluorescent tubes or gel them. An office building with hundreds and fluorescent fixtures on the other hand might be better a candidate for correcting to color balance of the fluorescents. Table 6.3 details each approach.

Gelling commercial fluorescent fixtures

When gelling fixtures that have frosted plastic panels, you can cut sheets to lay inside each fixture. If you have to gel tubes individually, place tabs of snot tape along the tube and roll the tube up in gel. Carefully cut away excess gel.

Rosco makes tubular sleeves of color correction gel that can make gelling tubes easier. You can also get clear plastic sleeves that are meant for protection in case of lamp breakage; cut and roll the gel inside them.

Theatrical gels for tints

As we have discussed, CTO and CTB gels are commonly used for coloring light in a natural way. For a more complete palette of tints, theatrical gels offer a vast array of alternative possibilities. You can find up-to-date lists of gel colors available from GAM, LEE, Rosco, Apollo by checking their Web sites (see Appendix F). Theatrical gels, also called *effects gels* or *party gels*, come in more than 400 shades (in sheets 21 in. × 24 in. or 20 in. × 24 in. or in 4 ft × 25-ft. rolls). Instead of using a ¼ CTO, the DP can choose from dozens of warming shades, such as gold, amber, straw, fire, salmon, pink, rose, apricot, and so on. *Cosmetic gels*, used primarily in theater productions, combine a slight diffusion with colors that are intended to enhance skin tones: cosmetic peach, burgundy,

Table 6.3 Strategies for matching mixed color sources

Strategy	Ceiling fluorescents	Tungsten fixtures	HMI fixtures	Windows	Fluorescent floor fixtures	Film stock and camera filters
Match to tungsten						
Used when the daylight sources are small and manageable (e.g., sound stage, a night scene, or a location with small windows)	Replace with high CRI, lamps with good tungsten-balanced color rendering. Add ¼ or ⅛ minus green as necessary. Gel warm whites with full minus green. Gel cool whites with fluoro filter.	Use tungsten lights to light the scene. Use it as is.	Apply full CTO gel.	Apply Sun 85 or full CTO gel.	Kino Flo (with KF-32 tubes)	Tungsten balanced film, no filter
Match to daylight						
Good approach in a room with many large windows	Replace with high CRI, lamps with good daylight-balanced color rendering. Add ¼ or ⅛ minus green as necessary. Gel cool whites with full minus green.	Apply full CTB gel (very inefficient).	Use HMIs to light the scene. Use it as is.	Use it as is or with ND as needed.	Kino Flo (with KF-55 tubes)	Tungsten-balanced film with 85 filter. Daylight balanced film, no filter.
Match to fluorescent daylight						
Resort to this if the ceiling lights must remain on and (1) there are too many fluorescent lights to gel or replace them all, (2) the lights are not accessible, or (3) there is no other alternative.	Cool whites. Use it as is.	Apply plus green 50 or full CTB and full plus green gel.	Apply full plus green gel.	Gel with window green.	Kino Flo with KF-55 tubes and full plus green Other types use same type of bulb as in ceiling fixtures.	Tungsten balanced film with 85 and FLB filter, or correct green in lab printing. Daylight-balanced film with FLB or take out green in lab printing.

rose, rouge, and so forth. Colors such as salmon, pink, and chocolate are also used to enhance skin tones. Straw and bastard amber often simulate a low afternoon sun or a flame.

Film emulsions vary in their sensitivity to different colors. A tint may not look quite the same on film as it does to the eye. The effect of a colored gel tends to be exaggerated when photographed, because although the human eye constantly adapts to the prevailing color of light, the taking medium (the film emulsion or video sensor) has a single reference for white. It must also be remembered that tints must be compatible with the pigments of the wardrobe and set. The color of the light mixes subtractively with these colors. The cinematographer may even conduct screen tests to see on film exactly what effect a given tint will have on a particular face or costume. A test is also the best way to compare the effects of several possible tints side by side.

Saturated colors

A deeply colored gel effectively narrows the range of wavelengths to those of a specific color. For example, a red gel transmits only the wavelengths around 650 nm. The gel absorbs all other wavelengths. The more deeply saturated the gel, the more heat it retains and the more susceptible it is to losing its color and melting. Pairing tungsten lights with red, orange, and yellow gels and HMI or arc lights with blue and purple gels uses the fixture's light spectrum more efficiently and puts less stress on the gels. Protect saturated gels by affixing them away from the heat of the lens, on the barn doors or a grip frame. *Heat-shield* is a clear, heat-resistance film used to protect colored gels from fading or melting under heat stress. Leave a couple inches of space between the heat-shield and the gel. Rosco's *Therma-shield* is a beefier (and more expensive) version that will hold up better than standard heat-shield films. PAR lights and 2k open-face units often require heat-shield, especially with dense colors.

Heat-shield retards the fading of a gel but is ineffective when a light is simply burning through a gel. In that case, the gel must be placed further from the source, spreading the light over a greater area of gel.

Additive mixing of colored light

When different colored light overlaps, it mixes to make new colors. RGB LED lights and multi-circuit cyc strips use additive color mixing to create a wide variety of colors from just three or four color sources.

The primary colors of light are red, blue, and green. By mixing these three colors of light, a gamut of other colors can be made. The intersection of two primaries makes the secondary colors (cyan, magenta, and amber). Theoretically, if three lights gelled primary red, blue, and green are aimed at a white surface with their beams overlapping, as in Figure 6.5, the area of intersection of all three lights is white.

The colors that are achievable by mixing light sources can be represented very simply on the CIE chromaticity diagram. If you plot the color point of two colored light sources on the diagram, the colors that are achievable by additive mixing varying amounts of those two colors are described by the straight line drawn between the two points. If you plot the color points of three colored light sources on the diagram, the range of colors achievable by mixing varying amounts of the three colors are contained within the triangle formed by the three points. As we will see in Chapter 10, some colored LEDs fixtures employ multiple colors in order to achieve an even wider range and more subtle control of color through additive color mixing.

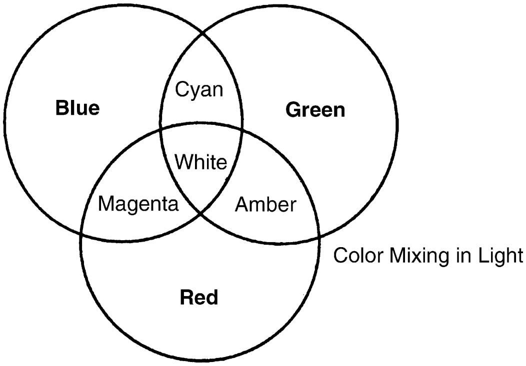

FIGURE 6.5

Additive mixing of colored light. The overlapping of all three primary colors theoretically creates white light. The combination of two primary colors creates the secondary colors (amber, cyan, and magenta).

(Reprinted with permission from Backstage Handbook *by Paul Carter. New York: Broadway Press, 1988.)*

Subtractive mixing of colors

When two gels are combined in one light or when colored light is directed at a colored surface, the colors combine subtractively—only the colors common to both are seen. Having a feeling for subtractive mixing is important for anticipating how the set, wardrobe, and actor's skin tone appear in tinted or colored light. A red light directed at a blue-green dress, for example, will turn the dress black.

BRIGHTNESS

Methods of control

There are many ways to adjust a lamp's intensity:

Scrims: Dropping a scrim in the light is the fastest and easiest way to reduce intensity without affecting anything else.

Distance: It is often surprising how little you need to move a light to make a big difference in the brightness. This is because the intensity of a light decreases in proportion to the square of its distance from the subject. This is known as the *law of squares* or *inverse square law*. Figure 6.6 shows that, if a fixture produces 120 FC at 10 ft., at twice the distance (20 ft.) the intensity is *one-quarter*, or 30 FC. At three times the distance (30 ft.), the intensity is *one-ninth*, or about 13 FC. (See "Falloff—Your Friend, the Inverse Square Law" section, later in this chapter.)

Flood or spot: Flooding dims the light and increases its coverage; spotting brightens the light and narrows its coverage. With PAR lights, you can change to a wider or narrower lens.

Dimmers: Dimmers provide a variable control of intensity and can be controlled remotely and used for light cues and programmed lighting effects. Dimming a light also reduces its color temperature. See the section "Dimmers" later in this chapter.

Nets: Nets are especially useful to control a selected portion of the beam. They are framed on three sides and open on one side. The open side makes it possible to hide the shadow line of the net, also called the *grip single* or *grip double*.

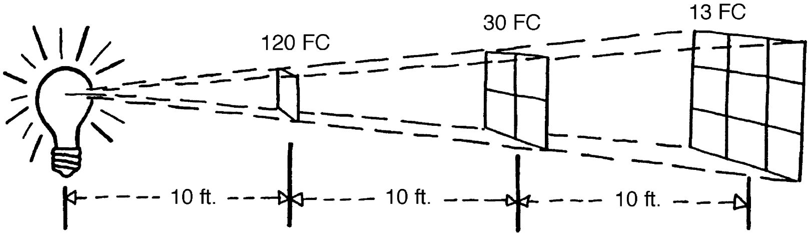

FIGURE 6.6

Inverse square law (law of squares). If a square surface of 1 ft. × 1 ft. is illuminated to 120 FC 10 ft. from the light source, at 20 ft. the same amount of light is now spread over a 4-ft. × 4-ft. area. The amount of light is therefore a quarter of what it was at 10 ft. (120/4 = 30 FC)

Fingers and dots: Fingers are used to reduce the intensity of a sliver of the beam. Dots are used to reduce the intensity of a very small circular area and can be used to even out hot spots in the center of beam field. Both come as single nets, double nets, silks, and solids.

Bobinette: Black net fabric that comes in bolts. It is handy, because it can be cut to any shape and size and draped or taped in place. It would be a quick way to dim down a too-bright neon or fluorescent practical, for example.

Neutral-density gel: Neutral-density gel is useful for controlling the brightness of a fixture that has no flood/spot control or scrims, such as an ellipsoidal spot.

Diffusion: Diffusion media dim and soften the light. The many kinds of diffusion media affect brightness and softness to varying degrees.

Wattage: You can replace the fixture with a bigger or smaller unit or, in some instances, replace the globe with a higher or lower wattage (bulb substitutions are listed in Table B.3).

Shutters: Shutters can smoothly reduce the amount of light getting to the subject. They are handy when the light level needs to change during a shot.

Falloff: Your friend, the inverse square law

A tiny Kino Flo placed 2 ft. from an actor's face gives the same light level as a 2k at 15 ft., or a 20k at 45 ft., so which one would you use? The gaffer tries to use the inverse square law to his advantage, rather than fighting it. This can save a lot of time and grip equipment. If you use a *big* light and place it *far* from the action, the light level will be relatively *even* from one side of the acting space to the other. If you use a *small* light source and place it *close* to the actor, the light level will fall off quickly on the objects surrounding the actor. In Figure 6.7, for the subject lit with the 20k at 45 ft., the change in brightness within 10 ft. of the subject is only about ⅔ of a stop. For the subject lit with the 200-W softlight at 2 ft., the light level 10 ft. behind the actor is more than five stops less—total darkness on film. For the subject lit with the 2k at 15 ft., the background is a pleasing 1⅓ stops down from the subject's brightness. Note, however, that any subject that passes through the foreground position will be blown out by three stops. All three of these scenarios offer definite advantages in the right situation. A small light source up close will put less light on the backgrounds, allowing the DP to build more mood, and making practical lights and other highlights pop. A large light far away allows the actors

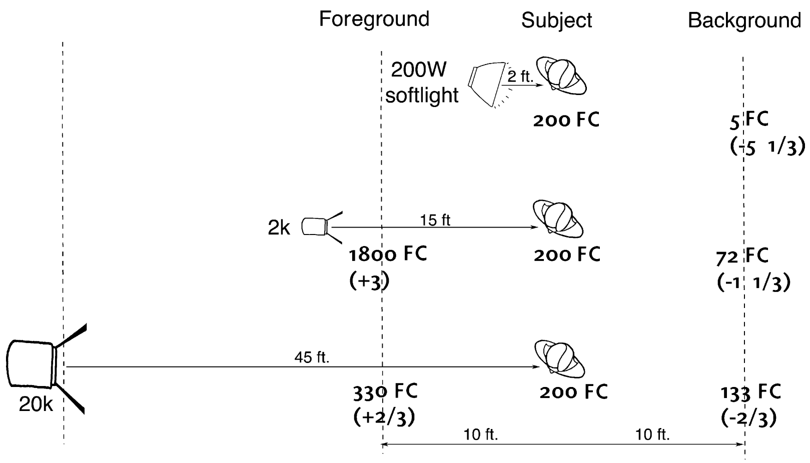

FIGURE 6.7

The inverse square law in practice. All three subjects are lit to 200 FC, but the light level in the foreground and background positions varies a great deal depending on where the light is placed. The numbers in parentheses give the difference in f-stops from the subject's position.

to move through a large space without drastic changes in level or having to light many areas separately. The size of the space, the motivating light source, the mood of the scene, the color and distance of the backgrounds, the details of a particular actor's face—these are all considerations that inform the decision of how to best take advantage of the inverse square properties of light.

Dimmers

Dimmers allow the gaffer to set light outputs to precise levels and to plan controlled changes in light levels during the scene. Very often these changes are designed to be invisible—hidden by the movement in the shot. For example, if the camera moves around the subject in such a way that back lights turn into front lights, the gaffer will put back lights on a dimmer. Of course, dimmer cues are also handy for creating effects where some sort of light appears or disappears in the scene.

A dimmer reduces light intensity by reducing the voltage to the light. Unfortunately, this in turn reduces the color temperature of the light, turning it gradually more yellow and orange as it is dimmed, as shown in Table 6.4. As a rule of thumb, the light changes 10 K per volt. Ten volts over or under line voltage increases or decreases the Kelvin temperature by 100 K. Dimmers are therefore useful only to the extent that the color change is not noticeable or when it is acceptable for the scene.

Several kinds of dimmers are used in film production:

Household dimmers: Small 600 and 1000 W household AC dimmers (*squeezers*) are often used to control practical lamps and small fixtures. Prepare each dimmer with a plug and socket so that it can be plugged into the line when needed. (Use grounded connectors and at least 14/3 wire for 1000 W dimmers.)

Socket dimmers: A 150-W socket dimmer screws into the bulb socket. They are handy for controlling low-wattage practical lamps.

Table 6.4 Color temperature and output at various voltages

	Color temperature		
Voltage (V)	*Kelvin (K)*	*MIREDs*	*Light output (%)*
120	3200	313	100
110	3100	322	75
100	3000	333	55
90	2900	345	38

Variac dimmers: The variac dimmer, an AC dimmer, is a type of variable transformer called an *autotransformer*. It can boost the power up to 140 V or decrease it to zero. These dimmers come in 1k, 2k, and 5k sizes (Figure 6.8). Typically, they are fitted with an on/off switch as well as a large rotary knob. Some have a three-way 120 V/off/140 V switch.

Plate dimmers: Plate dimmers are large variable-resistance dimmers that can be used with either AC or DC circuits running incandescent lights (Figure 6.9).

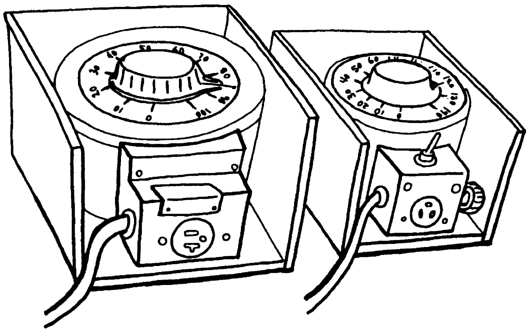

FIGURE 6.8

Variac dimmers in 2k and 1k sizes. The 1k dimmer knob is marked in volts, from 0 to 140 V. The scale on the larger variacs runs from 0% to 100%, which does not refer to volts. When set at 85%, the dimmer delivers line voltage (120 V). At 100%, the variac boosts voltage to 140 V.

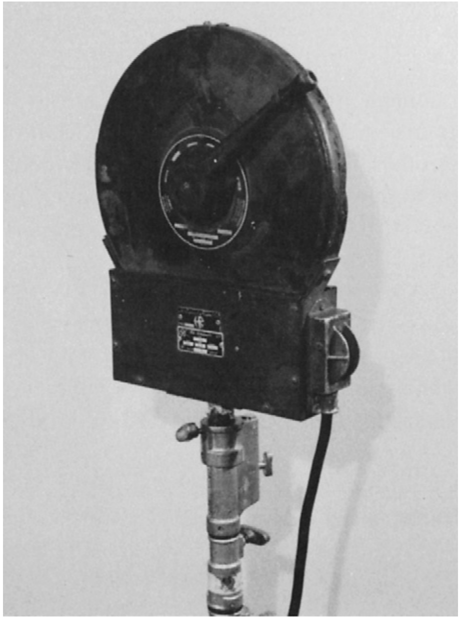

FIGURE 6.9

Mole-Richardson 2k plate dimmer.

(Courtesy Mole-Richardson Company, Los Angeles, CA.)

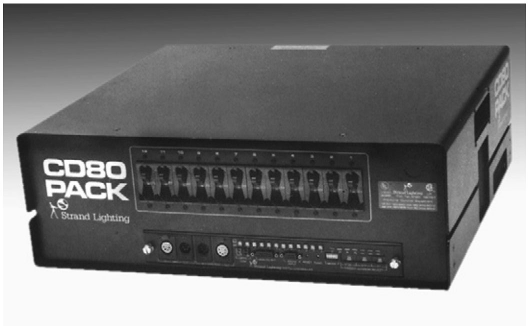

FIGURE 6.10

Strand CD80 dimmer pack. The 12-channel pack shown here has 12 dimmer circuits, each protected by a 20-A circuit breaker. The dimmer pack's brain (the controller card) is attached to the face plate (below the breakers), which contains the control cable inputs/outputs, diagnostic indicators, and setup switches.

(Courtesy Strand Lighting, Inc., Rancho Dominguez, CA.)

Electronic dimmers: The 12.4, 6, 12kW electronic dimmer packs are controlled via DMX512 control using a control console. 24kW stand-alone electronic dimmers typically provide a slider fader on the dimmer unit as well as a DMX512 port. When a large number of incandescent lights are to be controlled, dimmer packs of 6-12 dimmers (Figure 6.10) or large dimmer racks of up to 96 dimmers are employed. Electronic dimmers are covered in more detail in Chapter 13.

SHAPE, PATTERN, AND QUALITY OF LIGHT

Light can be manipulated in various ways as it travels from the light source to the subject. We can give it shape by cutting into the beam; we can break up the beam with patterns. We can also massage the quality of the light by altering the size of the light source relative to the subject. The quality of light establishes the hardness or softness of shadows, it changes the way light wraps around the subject, and influences the tonal gradation and the apparent contrast of the image. The quality of the light and our ability to manipulate shape and pattern are intertwined. We'll begin this section by discussing the qualities of hard light and techniques for shaping it. Then we'll look at ways we can transform the quality of light; we'll discuss the indispensable characteristics of soft light and the techniques necessary to control it.

Making cuts and patterns

In North America, it is the grip's job to set flags, nets, and large diffusion frames in front of lights; in Europe and elsewhere, they do things differently. The same goes for cucaloris and branchaloris breakup patterns (explained shortly). However, any lighting professional should understand the principals that apply. Flags and nets come in various standard sizes, as shown in Figure 6.11.

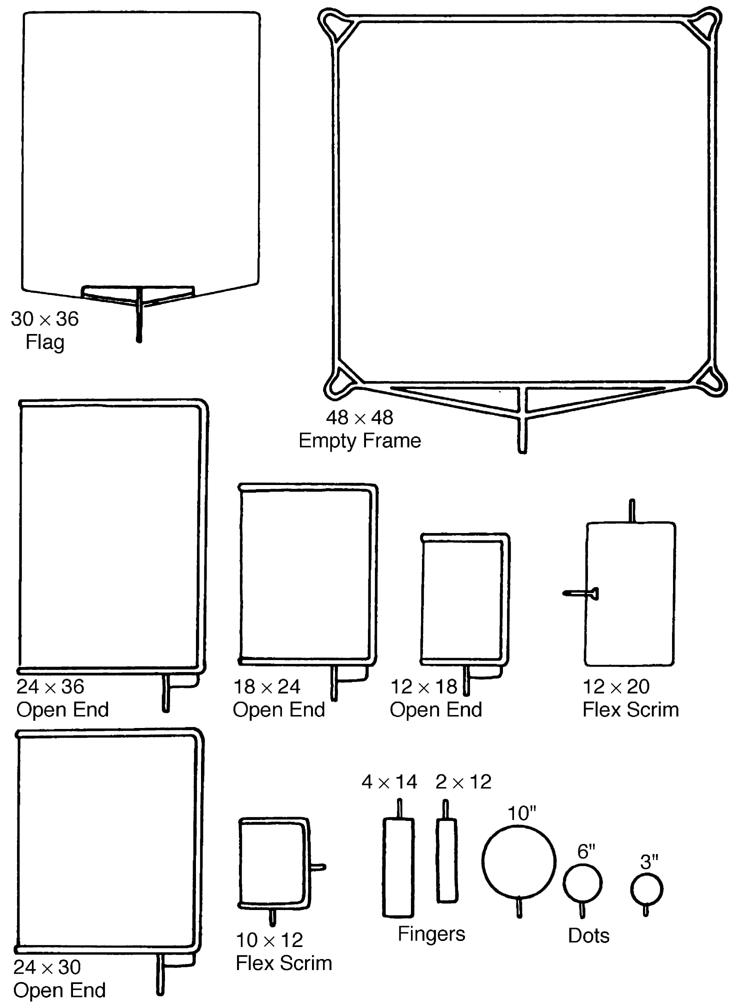

FIGURE 6.11

Common sizes of flags, nets, frames, and silks including fingers, dots, and 10-in. × 12-in. postage stamps.

Once a light is placed and turned on, the lighting crew cuts it off areas where it is not wanted (with barn doors or flags). Often a key light must be cut off a background wall, or when an actor stands closer to the light source the light must be reduced with a net or diffusion. The gaffer might like to break up the background with a pattern, a streak, or a line of shadow. A few simple but important rules apply when using any flag, net, pattern, or set piece (such as a window) in front of a light. To make a soft cut (fuzzy shadow line), place the flag closer to the light. To make a hard cut (cleanly defined shadow line), place the flag closer to the surface onto which the shadow falls. For example, if you put a slash of light on a background wall and want the light to gradually taper off toward the

top, use a soft-cut topper (a barn door works fine). If you want a hard, defined shadow line, on the other hand, place the flag well out in front of the light. For the sharpest definition, back the light up and place the flag as close to the wall as possible (without it encroaching into the shot). A larger flag may be necessary to cover the whole beam.

A topper is a flag or net used to cut the top of a light. Toppers are often used to keep light off background scenery, which also helps the boom operator avoid casting shadows on the walls. Similarly, *siders* and *bottomers* trim light from the side or bottom. A *lenser* cuts light off the camera lens to prevent flair in the filters and lens. A *courtesy flag* is set up to shade glaring light off the camerapersons, or others. When setting a *lenser*, a hard cut is preferable. Halfway between the camera and the light is usually an effective placement when practicable. If the camera is on a long lens (a telephoto lens), the flag can be placed close to the camera. However, when a wide angle lens is used, you will run into trouble with the flag encroaching into onto the shot and it must be worked closer to the light.

To avoid the encroachment problem, always place the stand on the off-camera side of the flag. First prepare the flag on the stand, then slide it in from the offstage side until the shadow covers the lens and filters. Ideally a lenser blocks light from the entire inner face of the matte box. If light hits the filters in the matte box, the image may flare.

With Fresnel lights in flood position, the beam width is roughly equal to the distance from the light. If the flag is placed 3 ft. in front of the light, a 2-ft. × 3-ft.-flag is sufficient. If a harder shadow is needed, use a longer cutter (24 in. × 72 in.) placed further from the light.

Use of the net

A net can reduce the intensity in a specific area with much greater accuracy than a half-scrim in the light. You can help hide the shadow line of a net by making a soft cut. If a double net makes an obvious shadow line, you can use two single nets clipped together and staggered, so the thickness builds up gradually. You can fine-tune intensity with a net by angling the net slightly. The more oblique is the angle, the thicker it gets.

Breakup patterns

A breakup pattern is very often used to give texture to the background of a shot. Breaking up the light with a tree branch, gobo pattern, Venetian blind, window pattern, or just random streaks of shadow gives the image greater contrast and tonal variation and helps set off the foreground subject. The gaffer may want to exploit whatever shadow-projection possibilities are offered by the set and set dressing: foliage moving in the wind, a slow-turning fan, water running down glass, lace curtains, a banister.

Again, for the pattern to be cleanly defined, the pattern maker must be as close to the surface as possible.

You get a cleaner shadow:

- From a point source than from a larger one.
- From a stronger light placed further away.
- From a Fresnel fixture than from an open-face reflector fixture.
- At full flood than when spotted in.
- From the edge of the beam than from its center.

- By removing the lens from the fixture altogether (though you also lose intensity and flood/spot control).
- By using a donut to remove the edges of the beam with ellipsoidal and xenon lights.
- Of Venetian blinds from a Fresnel if you place a C-stand arm through the center of the beam a foot or so in front of the fixture. (No one ever believes me on this one. Just try it.)

The distance also affects the size of the projected shadows. When close to the subject and far from the light, the pattern is of only slightly larger dimensions than the pattern maker itself. When the pattern-maker is very close to the light, however, the pattern is projected over a large area, extremely enlarged and distorted in shape—more expressionistic. Therefore, the size of lamp used, the size of the pattern maker needed to cover the beam, and the distance of the light and the pattern from the subject must all be taken into account before placing the light. In fact, these considerations may have to be taken into account when designing and placing the sets. For example, if a light is to shine through a window and needs to be placed a considerable distance from the window, ample space must be provided for lights around the set.

Cucaloris

A *cucaloris*, also called a *cookie* or *cuke*, is a plywood flag with foliage-shaped holes cut in it. It is used to break up the light into random foliage like splotches. A *celo cuke* is made with painted wire mesh and creates a more subtle effect because the mesh reduces the light rather than blocking it completely. A cookie does not look convincing if it moves during a take. For realistic moving foliage, use a branchaloris.

Branchaloris

A *branchaloris* is nothing more than a leafy branch placed in front of a light, held on a grip stand. It breaks up the light, projects the shadows of branch and leaves onto the scene, and can be made to move naturally using an effects fan.

Tape on an empty frame

To make lines through the light (to simulate the frame of a window, for example), take an empty frame (18 in. × 24 ft, 2 ft. × 3 ft., or 4 ft × 4 ft., depending on the size of the source and the frame's distance from it) and run strips of black tape across it. It is easiest to build the pattern with the fixture in place and turned on, so that you can see the effect it creates.

Altering the Quality of Light: Soft light

When light is bounced or diffused over a relatively large white surface, the quality of the light is altered in a fundamental way. When light moves away from a conventional light fixture, the rays of light are diverging from one relatively small area (the reflector and lamp). In contrast, when light moves away from a soft source, the bounced or diffused rays move away from all points of the diffuse luminous surface. If you think of it from the point of view of the subject being lit, a large soft source enables light to find the subject from multiple angles. This results in three qualities that are often very desirable:

1. *Soft shadows*: No clean, sharply discernible line is projected. The shadow lines are broad and fuzzy. Shadows appear as gradations of tone, so that the entire image is imbued with a softness that is natural and also very beautiful. The fuzzy quality of soft shadows also makes them easier to hide in situations where multiple shadows would be distracting.
2. *Soft light wraps around the features of the subject*: A face lit from one side by hard light is like a half moon (bright on one side and black on the other), whereas lit by a large soft source, it shows a gradual drop off of light from one side to the other. Soft light tends to fill in blemishes in the skin. The overall picture has a full tonal range, light to dark, with no harsh shadow lines and lower overall contrast than when lit with harder light.
3. *Interesting reflections*: When lighting shiny or glossy subjects or surfaces with glossy finish, a soft source is reflected as an amorphous highlight. Hard light, on the other hand, is reflected as a bright, glaring hot spot.

A soft source can be used to create a soft highlight in dark wood, bringing out dark furniture or paneling by catching a reflection of the light source. The gaffer places the light where it is seen by the camera as a reflection in the surface. Especially in cases where you don't want to throw a lot of light onto the walls, this approach yields a subtle, more natural effect.

Along the same lines, a soft source makes a nice eye light. It reflects in the shiny part of the eye, giving the eyes a special brightness. A large, soft source reflected in this way need not actually shine a lot of light onto the subject; it need only be bright enough to create a visible highlight reflection.

Softness of light

Three factors influence the softness of light:

- the size of the surface of the source,
- its distance from the subject,
- and the thickness of the diffusion material (the amount that the particular diffusion material is able to scatter the rays of light in proportion to the amount of light that passes through the material largely unaltered.)

The larger the source, the softer the shadows and the greater the wrapping effect, because a larger source yields more light rays at angles that encircle the features of the subject. This is why it is important when focusing a light fixture onto a diffusion frame or bounce board to completely fill it with light. The surface of the diffusion frame or bounce board becomes the source of light for the scene; the larger the source, the softer the effect.

The smaller the subject, in relation to the face of the source, the more the light engulfs it. If the subject is too small, it becomes overwhelmed and the image starts to appear flat.

Obviously, the size of the source in relation to the subject also depends on the distance between them. The further away the source, the smaller its effective size. (The sun, for example, is a very large source but, as it is 93 million miles away, its rays are completely parallel, so direct sunlight is relatively sharp.)

Bringing a soft light in as close to a subject as possible maximizes its softening effect. This also localizes the light, creating a soft pool around the actor, which falls off very quickly. The fast fall off is due in part to the close proximity of the source to the actor—by way of the inverse square law.

Light also falls off more quickly from a soft source than it does from a hard one because light rays are diverging to a greater extent.

Controlling soft light

A DP often wants to control the foreground lighting and background lighting separately and light the actors without also flattening out the background. One can do this by cutting and containing the lighting with flags, blackwrap, and the like. Soft light is more difficult than hard light to cut and control, and the larger the source and the heavier the diffusion, the more difficult it becomes. The larger the source, the larger the flags required to block the light. Boxing in a 4-ft. × 4-ft. frame of heavy diffusion typically requires 4-ft. × 8-ft. flags. Large cutters, 2-ft. × 6 ft., are necessary as toppers, placed well out in front of the source. Boxing in larger frames (8-ft. × 8-ft. or 12-ft. × 12-ft.) can require a lot of grip work. Flags and nets used close to a large source are ineffectual: the light engulfs the flag. To be useful, the flag must be far enough from the source that it blocks a direction the light is traveling, rather than merely blocking a portion of the face of the source. Grips often need to fabricate a *teaser* 12 ft. or 14 ft. long by stapling a length of duvetyn to a 1×3 batten.

Nets are often ineffective with a large soft source. You can, however, use a solid where normally you would use a net. Because the shadow is so nebulous, the flag serves to create an area of lesser brightness, rather than a cut. The flag can be angled to increase or decrease its effective size.

Controlling soft light using grids and egg crates

The best way to easily contain soft light is using an egg crate or louver directly in front of the diffusion surface. Lighttools makes fabric egg crates (Soft Crates) for all types of chimera-type light banks as well as for larger diffusion frames, butterfly sets, and overhead frames from 4 ft. × 4 ft. up to 20 ft. × 20 ft. (Figure 6.12). A Soft Crate is a collapsible fabric grid that controls the light by

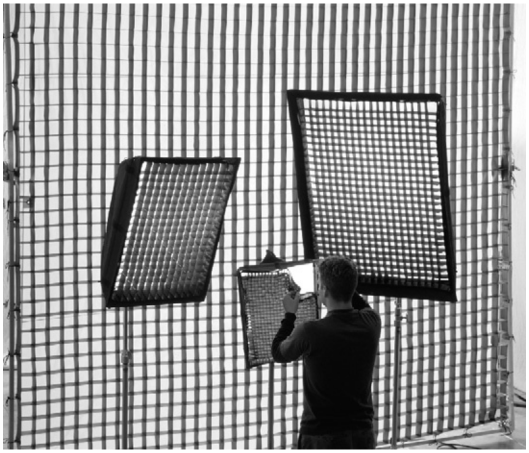

FIGURE 6.12

Lighttools Soft Crates being made ready for use on three lightbanks and a 12-ft. × 12-ft. frame.

(Courtesy Lighttools™, Edmonton, Alberta, Canada.)

dividing the source into bite-size portions, or cells. The Soft Crate reduces neither the softness nor the brightness of the light source appreciably but does control how much the light spreads to the sides. This approach has the advantage of being extremely space efficient. It avoids cluttering the set with a forest of flags and C-stands, which can be a real problem, especially in smaller sets. Soft Crates used on large frames come in four cell sizes, referred to by their maximum beam spread: 20°, 30°, 40°, or 50°. Soft Crates for Chimera-type light banks are offered in 20°, 30°, 40°, 50°, and 60° cell sizes.

Although the main purpose of an egg crate is to contain the light, on larger frames it also tends to even out the brightness of the light as you move toward the light source. This happens because as you move closer to the light source, the fabric cells occlude progressively more of the diffusion surface. The egg crate effectively reduces the exposure range in the acting space by reducing the rapid increase of brightness, what DPs like to call *sourcyness*, showing the audience the light source. The egg crate effectively circumvents the inverse square law.

Diffusion

Diffusion materials

There are four basic types of diffusion material, each with its own character: polyester-based frost and white diffusion, fabrics (such as silks and nylon grid cloth) spun glass diffusions, and silent diffusions. Each type is manufactured in several densities (Table I.10).

Polyester-based diffusion materials provide a wide range of calibrated density levels. A light diffusion such as opal or Hampshire frost, yields slight beam spread and softening, but still maintains a discernible beam center. The original direction of the beam is still dominant. A medium-weight diffusion material, such as 250, diffracts much more of the light. As a result, the beam spreads as it passes through the material. As the diffusion surface itself becomes the source of rays of light equally with the light fixture, the effective size of the source is enlarged to the size of the diffusion frame. Shadows are softened. The light starts to wrap around the edges of objects.

A dense diffusion, such as a heavy frost, 216, or grid cloth, causes a wide beam spread. The original direction of the beam becomes secondary to the diffuse multidirectional rays emitted from the diffusion material. The light rays are deflected in all directions over the entire area of the diffusion frame. This creates the ideal source for soft, wrapping light because the greatest number of light rays are diverted at angles that can accomplish these ends and the dominant direction of the light from the fixture is completely removed. It creates an even field of light with no discernible beam center or edge.

Fabrics such as silk, muslin, and grid cloth, often are used on large grip frames. The characteristics of fabrics are listed in the table on the top of the next page.

Spun, or spun glass, is used mainly on very hot little light fixtures, because it is very heat-resistant. Spun gives the beam a mild soft edge but with minimal spread, so that the shape of the beam and the effectiveness of barn doors are maintained. Silent diffusions, such as soft frost and Hilite, are made of a rubbery vinal material that does not rattle and crinkle when caught by wind, as polyester-based diffusions do. These materials are not as heat-resistant as other diffusion material, however, and should not be used directly on a light fixture.

Diffusion on the fixture

As with colored gel, label each piece of diffusion material when it is cut from the roll. Mark the type on the corner of the piece with an indelible marker.

Fabric Diffusions		
Material	**Approximate Reduction**	**Notes**
Full Grid Cloth	2.6 stops	Available in “silent” and “noisy” versions. Grid cloth is light-weight and very durable.
Half (Lite) Grid Cloth	2.0 stops	
Quarter Grid Cloth	0.7 stops	
Polysilk (full silk)	1.6 – 2.6 stops	Heavy density with moderate diffusing effect. Light passing through silk casts a relatively hard shadow, but the silk helps to fill. Polysilk is a synthetic available in white and black.
China Silk (half silk)	1.0 stop	Medium density. Natural fabric available in either warm white or black
Quarter Silk	0.6 stops	Very light density diffusion.
Natural (unbleached) Muslin		Muslin is a heavy weight fabric used for cycloramas and ceiling pieces, also used as a lighting tool. Very wide seamless widths (up to 39.5 ft). Unbleached muslin has a yellow tint, which warms the light.
Bleached Muslin		Bleached muslin is less yellow than unbleached, but also retains some warming effect.
Diffusion Cloth		Very soft diffusion used on light banks and overheads.

Data varies depending on the particular material used by the manufacturer.
Sources: The Rag Place, Matthews Studio Equipment.

Attaching diffusion material to the barn doors of a Fresnel or open-face light takes the hard edge off the beam. It diffuses the light, evens out the intensity across the field, and reduces or removes the central hot spot.

To create as large a source as possible, open the barn doors wide and attach the diffusion material to the outside. When using dense diffusion medium, the flood/spot mechanism works in reverse. To maximize the light output, flood the light to fill the diffusion with light. Maximum output is often found just shy of full flood.

Diffusion attached inside the barn doors allows them still to have some effect and creates fewer problems with spill and reflections off the back of the diffusion; however, it does not increase the size of the source and therefore does little more than take the curse off the hard light.

Other ways of making soft light

Croney cone: The Croney cone, named for its inventor, renowned DP Jordan Cronenweth, ASC (*Blade Runner*), is a cone that fits in place of the barn doors on the front of the light. A frame fitted with grid cloth or some other diffusion slides into slots on the front of the cone, turning the Fresnel into a soft source with a larger face (Figure 6.13). The diffusion frame can be exchanged easily when a different type of diffusion is desired.

Chimera: Chimera Photographic Lighting makes a variety of collapsible, heat-resistant, fabric soft boxes (Figure 6.14) that incorporate a great many refinements on the basic Croney cone design.

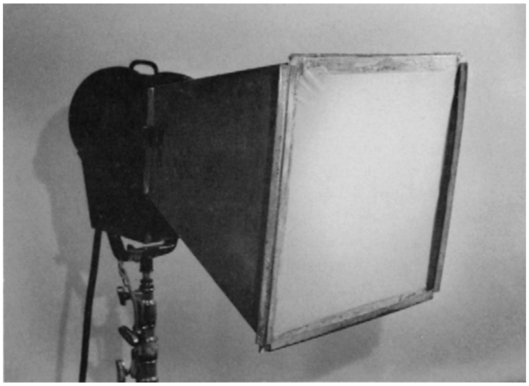

FIGURE 6.13

A Croney cone.

(Equipment courtesy Hollywood Rental, Sun Valley, CA.)

FIGURE 6.14

Chimera lightbanks in use on a variety of heads (from small to large): a Video Pro bank on a 150-W Dedo fixture, a small Quartz bank on a 1k baby (fitted with a fabric louver), and large one, a 2k junior and a Daylight bank on a 2.5k HMI.

(Courtesy of Chimera Photographic Lighting, Boulder, CO.)

Chimeras are made of heat-resistant fabric stretched and held in shape by flexible, interior, stainless-steel poles. The interior fabric is soft silver reflective material that increases light output and further diffuses the light. Accessories include 60° and 90° honeycomb grids and louvers. A second interior diffusion baffle can be added to double-diffuse the light. This ensures that even an intense and punchy light source will be fully diffused.

Chimeras can be fitted to almost any Fresnel, PAR, or open-face fixture in place of barn doors. A "speed ring" is needed to adapt the chimera to each light. The chimera light banks are available in four models. Video Pro and Quartz banks are standard depth and are best used with open-face fixtures. Daylite and Daylite Junior banks are deeper; they are useful for narrower-beam fixtures, such as Fresnels.

Lights will char and damage the flaps that close the chimera around the face of the light. The flaps are fitted with Velcro, so they can be folded back away from the face of the light when necessary.

Homemade soft box: Soft boxes can be made quite simply out of light lumber, foamcore, staples, screws, and diffusion material. Remember that these materials are flammable and lightbulbs get very hot. These kinds of homemade devices are no longer allowed at the studios, because they pose a fire hazard.

Lanterns: Gaffers have long used paper lanterns for soft localized glowing light, or overhead ambient light (Figure 6.15). The popularity of lanterns inspired manufacturers to come up with more sturdy and durable, fire-resistant fixtures of this type. Chimera's pancake lantern is shown in Figure 6.16. Lanterns are typically used on a variac, positioned just off screen and used in close.

FIGURE 6.15

The gaffer hand-holds a paper lantern in order to get light onto the actors' faces in a fight sequence. Lanternlock makes a paper lantern bracket/socket combination that securely attaches to a standard paper lantern so that it can be held in any position and mounted to a C-stand. Paper lanterns come in various sizes (12-, 24-, and 30-in. spheres) as well as rectangular boxes. Rig the lantern to a C-stand, with a photoflood bulb in a porcelain socket (do not use the 60-W plastic sockets sometimes sold with the lanterns; the photoflood bulbs will melt them).

(Photo courtesy Daniel Watchulonis, Lanternlock and The Film Department.)

They are easy to rig over a table in order to get light to emanate from the center of a circle of actors. A large ball hung above the set achieves a nice low ambient light level.

Bounce light

Simply bouncing a specular source off a white surface can create soft light. Following are some examples.

Bead board and foamcore: In many situations, a piece of white board can be used to bounce existing light onto the shadow areas of the face to reduce contrast. This is especially common when shooting outside in direct sunlight, where the contrast is very high. A 2- or 4-ft. square of foamcore, taped to and reinforced by a piece of bead board, is standard equipment for fill light.

To fill a fairly large room with soft light, a strong light, such as a 2500-HMI PAR, can be aimed at a 4-ft. × 4-ft. or 4-ft. × 8-ft. piece of bead board or foamcore (Figure 6.17).

Remember that the angle of incidence equals the angle of reflection. If you put the bounce board up high and angle it downward, you can place the lights below and in front of the board, pointing up into it.

Show card, cove light: In a small room where it is difficult to hide lamps, you can tape a piece of white show card into an off-screen corner (Figure 6.18). The reflected light can be better controlled if the show card is curved into a parabola. The fixture is hidden under or above, pointing at the show card, creating a soft light from that direction. You can also use a silver or gold show card.

Ceiling: A fast and easy way to fill a room with soft, even illumination is to bounce a strong light off a white ceiling. If the ceiling is not white, you can rig a sheet of foamcore to the ceiling.

FIGURE 6.16

Lantern fixtures, like this 35-in. pancake lantern made by Chimera, offer a soft glowing light that is lightweight and easy to rig over the acting area. The black skirt helps control the light, and keep light off the walls. Lanterns like this are made of rugged, nonflammable material. Manufacturers offer these fixtures in a variety of sizes typically with medium screw base (up to 500W) and mogal base lamp sockets (up to 1000W). HMI versions are also available. (Courtesy Chimera Photographic Lighting).

Griff: To create a very big, soft source that might simulate skylight when shooting inside a studio or when a large area needs to be covered with soft light, the gaffer may bounce light into a 12- or 20-ft. square of griffolyn. A couple of large HMIs—one on each side—do the trick. For exterior scenes, a griff works the same way, bouncing sunlight.

MOVEMENT

The final property of light that can be manipulated is motion: the jumping glow of a television screen; the dancing flames of a fire; the passing of car headlights at night; disco and concert lights; the movement of a handheld lantern or flashlight; a swinging bulb hanging from the ceiling; the projection of rain running down a windshield; the slow, smooth motion of sunlight through an airplane's windows as it banks and turns. Movement contributes to a scene's naturalism, mood, and visual interest.

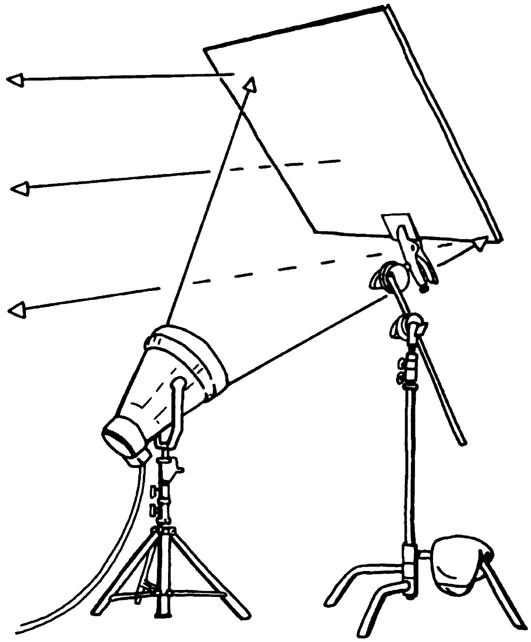

FIGURE 6.17

A strong, large, soft source produced by bouncing a 2500-W HMI PAR off a 4-ft. × 4-ft. bead board.

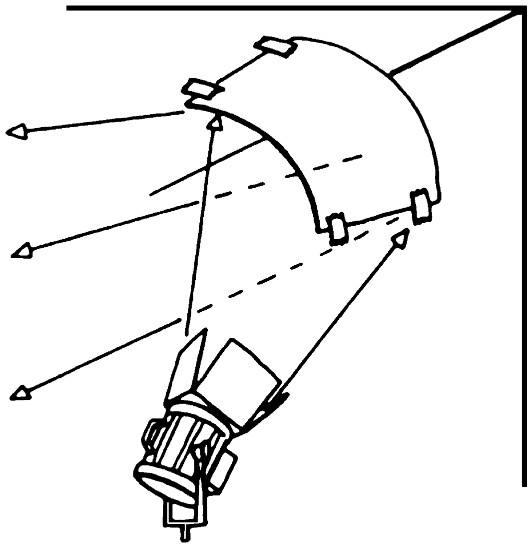

FIGURE 6.18

A show card taped into a corner creates a soft source without rigging a fixture into the corner.

Flicker effects: Television screen, flame, and fire

Sit in a dark room with only the television on, but don't look at it. Watch the way the light shifts on the walls and faces in the room. You will notice that the blue television light quickly changes in intensity and color when there is a cut on screen and gradually shifts in intensity as the camera pans or as characters move around.

The pace of the shifts depends on what you are watching. A music video creates a constantly changing image. Old movies, on the other hand, tend to play scenes in wide master shots or intercut reverse close-ups, leaving at least several seconds between cuts. When you create an off-screen television effect, you must find a way to mimic the pace of the shifts with the intensity of the light.

There are many different ways to do this, and any method that works is as good as another. A common way is to use a softbox with several small lights inside it. Use blue gel and diffusion material on the front of some or all the lights, as desired. To make the lights flicker, some sort of controller must be used.

Flicker generation

Gaffers have devised lots of ways to flicker lights to create television screen and flame effects. These range from really complicated gadgets such as a circular disk of mercury switches to simply waving arms in front of two short fluorescent tubes. The latter approach makes a nice effect because the light does more than just change intensity; it actually shifts slowly up and down, which reads well on film.

Flicker boxes are also commonly used to create a fire effect. In order to simulate the movement of firelight side to side and up and down, at least two or three lights are needed, each with a random flicker. A variety of electronic flicker boxes such as those shown in Figure 6.19 are also on the

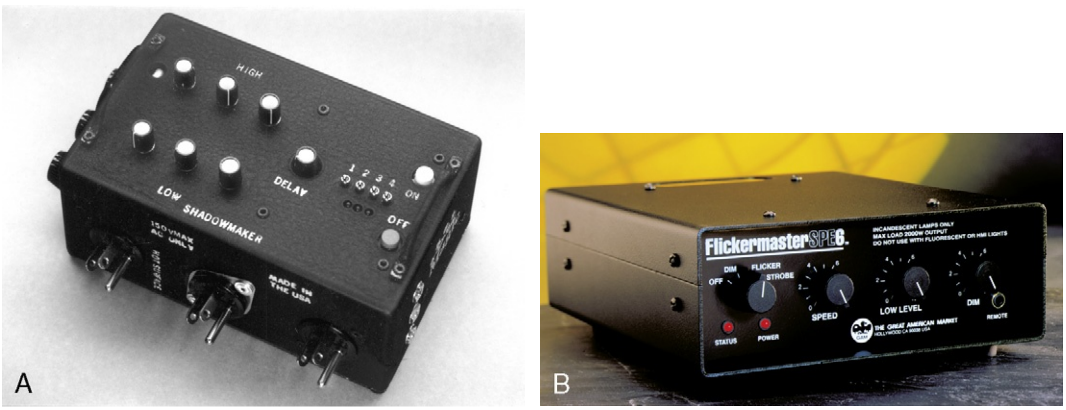

FIGURE 6.19

(A) Magic Gadgets flicker box supplies three 20 A circuits, each of which can be set to flicker up to a set peak and down to a set base level. The three circuits can be programmed to create a variety of chase effects, fire effects, and television effects. The box can also serve as three 2k dimmers. (Courtesy Magic Gadgets Inc., Seattle, WA.) (B) The Flickermaster is a single-circuit 2000 W flicker box with adjustable high and low flicker intensity and adjustable speed that can be used as a dimmer, flicker, or strobe generator.

(Reproduced by permission of GAMPRODUCTS, INC., Los Angeles CA.)

market. A flicker box typically creates increase and decrease in intensity at random intervals. The rate of flicker as well as the brightness of the light at its peak and lowest intensities can be set with controls. Some flicker boxes also make blinking light effects and lightning flashes. Flicker boxes having three circuits can produce coordinated flicker effects and chase effects. Most flicker gags involve small lights, but Magic Gadgets also makes 2, 6, 12, and 24k dimmers and effects generators. Newer ones are DMX512-controllable. These can also be used in conjunction with an Optical Interface. By placing an optical sensor near a light source, dimmers can be made to mimic the source. This is useful for fire and flame effects, and when actors operate practical lamps in a scene.

Another way to make a convincing fire effect is to use actual fire. If practical considerations (such as the location, the need for fire marshals, and so on) allow it, a fire bar (a propane gas-fueled pipe with holes along it) can be supplied by the effects department and used as a portable lighting source. If the intensity of the flame is insufficient, supplemental light can be imbued with the look of flame by shining a fixture through the flame of the fire bar.

Other moving light effects

Lights are often mounted to a crane or dolly or handheld by an electrician to make the light move. Reflecting a PAR 64 into broken mirror fragments in a shiny silver tray of water creates lively water striations. Sequences of dimmer cues can be set up to create nice shifts in angle and color. Various special effects lights can be used to create moving projections (*scene machine*) or dynamic concert lighting effects (automated fixtures, see Chapter 11). There are many exciting ways to move light.

CHAPTER

Electrician's set protocol

7

SET PROTOCOL

Staging area

Upon arrival at each new shooting location, one of the first jobs is to establish a staging area where electrical equipment is kept, ready to go onto the set when needed. The best boy will have scoped out a spot that is convenient to the set but not so close as to block access. Stake out the good spot early before another department claims it. The entrance to the staging area must be clear of obstructions. You don't want a line of director's chairs sitting in front of the area. You need to be able to carry equipment in and out easily.

The electricians can "head-up" a selection of lights, Noah's Arc-style (two of each) on stands in the staging area, ready to be brought into the set when called for. Line up the lights on stands. Organize them in rows—row of midgets, row of tweenies, row of babies, row of juniors, and so on—so that each type of light is readily accessible. Skinny up the legs of the stands so they can be packed together closely. To be totally proper about it, the lights should be arranged with the stand fully lowered, T-handles lined up in a straight line down the back of the stand, power cord hanging on hanger, switch is OFF, gels and scrims hanging on the stand (not in the light), and doors closed.

The staging area should be arranged in an orderly fashion for easy access to all the equipment. The set carts typically provide a place for the gel crate, gel rolls, boxes of practical bulbs, household dimmers, variac dimmers, tape rolls, clothespins, and similar electrical expendables. A crate each of 25- and 50-ft. stingers are set out ready for use.

When a light, stinger, or cable is no longer needed on the set, it goes back to the staging area, where it will not create clutter. The light should be "head wrapped": the stand fully lowered, the cord coiled, the barn doors closed, and the scrims removed and hung on the stand. If a particular gel or diffusion is being used frequently, store it in the scrim box. Some gaffers like to have specific precut gels kept with each light.

Lighting the set

Electricians have to be alert and always have one eye on the gaffer. You tune into the sound of his voice and learn to pick it out from the general rumble of noise. An experienced electrician has a sense of the ebb and flow of activity on the set and knows when he or she needs to work fast and when there is time to spare. When lighting begins on each new setup, all the electricians should automatically come to the set. There is a great deal of activity as the broad strokes of the lighting are put

Set Lighting Technician's Handbook, 4e. DOI: 10.1016/B978-0-240-81075-1.00007-6

in. The director's monitor and the camera dolly should be provided power immediately if need be. A period of tweaking and adjusting follows the broad strokes; a few small lights may be added.

Each time the first AD announces a new shot, the electricians working the set should quietly get close to the lights that they might need to move and watch the gaffer and DP for instructions. Even when lighting activity is at a minimum, one electrician should always be on or near the set. Before you leave the set to grab a soda, conduct business, or go to the restroom, be sure that another electrician is on the set and knows that you are stepping out. If the gaffer needs to step out, he will assign a set electrician to cover him, and that person must remain alert to the DP until the gaffer returns.

Setting lights

The gaffer gives an instruction: "Put a baby over in that corner to backlight these two actors. Give it opal and quarter CTO." You need a baby stand, a baby with scrim set and barn doors, and precut gels and diffusion. You probably also need a 25-ft. stinger to run power to the light.

A complete set of appropriate-size scrims and a set of barn doors should be brought to the set with every light. Hang the scrim box on the stand. When the gaffer wants a little less from a light, you should be able to drop in the scrim in seconds. It is bad form to have to search for scrims. They should always be with the light.

Each *raised stand* should have a sandbag placed on the leg. The more time you spend on sets, the more you see just how easily stands are toppled. It becomes second nature to check that stands are properly bagged. Similarly, when working in a wind, around Ritter fans, or around helicopters, the grips may need to tie guy lines (no less than three) to the top of the light stand and secure them to stakes driven well into the ground. Prop-wash from a helicopter will blow over a Dino on a supercrank like a piece of paper, even with 130 lb. of sandbags on it.

Focusing lights

Ideally, an electrician has some idea what the light is to be used for. Either the gaffer explains it briefly when calling for the light or the electrician already knows because the gaffer and DP use particular lights for the same general purpose on each setup and the electricians have set similar lights numerous times before. The electrician comes in with the light, sets it up, powers it, aims it to light the prescribed area at approximately the desired angle, adjusts the barn doors, and has the diffusion ready—all without turning the light on. The electrician then notifies the gaffer he or she is ready. When the gaffer gives the go ahead, the electrician turns the light on and makes any small adjustments called for by the gaffer.

Don't make the mistake of turning on the light as soon as you arrive with it, especially if you're not clear on exactly what the gaffer has in mind. The gaffer and DP may be in the middle of focusing other lights or taking light readings. Usually background lights can be turned on and focused by the electrician without the gaffer. The gaffer is notified for final approval after the light is totally set, before the electrician walks away. This saves the gaffer time. But, if in doubt, check before you hit the ON switch.

While the electrician handles the light, the gaffer either stands on the set with the light meter or views the scene from the appropriate camera angle. Very often the gaffer starts with the light at full spot to aim the beam. Some gaffers will hold out a fist where the beam should be spotted. The electrician spots the light onto the gaffer's hand, then returns the light to full flood. Another way gaffers sometimes focus the light is to view the light fixture through a contrast glass. The gaffer then directs

the lamp operator with hand signals (Figure 7.1) or verbal instructions. Here are some common instructions:

Pan lamp-left or lamp-right: Lamp-left is your left when you face the direction the light is facing. Lamp-right is your right.

Camera-left or camera-right: Camera-left is your left when you face the direction the camera is facing. Camera-right is your right.

Tilt up: Tilt the light up.

Tilt down: Tilt the light down.

Flood it out: Turn the flood/spot knob slowly toward flood until told to stop. Reply, "Flooding."

Full flood: Go directly to full flood.

Spot it in: Turn the flood/spot knob slowly toward spot until told to stop. Reply, "Spotting."

Full spot: Go directly to full spot.

Stem up: Raise the stand.

Stem down: Lower the stand.

Walk it back: Move the stand and light back.

Walk it in: Move the stand and light closer to the action.

Walk it upstage: A term that originates in the Shakespearian theater, where the stage is sloped toward the audience. Upstage is away from the audience. In film and television, it is taken to mean the direction away from the camera (e.g., the upstage lights are backlights). See Figure 7.2.

Walk it downstage: The direction toward the audience, in our case, the camera (for example move the junior downstage 3 ft.).

Walk it offstage: As if the camera is the audience. Offstage is the direction away from the center of the shot laterally (for example, always place the C-stand on the offstage side of the light).

Walk it onstage: The direction toward the center of the shot laterally (for example, "You can move your light 2 ft. onstage before you get in the shot").

Lock it down: The light is aimed correctly; tighten the T-handles to lock that position.

Walk away: It's perfect. Make sure that everything is secure. You're done with that one. "That's a purchase" is a similar phrase.

A scosh: Technical term for an increment slightly less than a smidge or a tad, as in "Flood it out a scosh."

Door it off the back wall: Lower the top barn door.

Drop a double: Put in a double scrim. Reply, "Double in" when finished. You also hear expressions like "Slow it down" or "Bring it down to a dull roar."

Drop a triple: A double and a single in a light.

Home run: Two doubles in a light.

Grand slam: Two doubles and a single in a light (someone picked the wrong light).

Pull the wire: Pull out all scrims. Reply "It's clean" when no scrims remain.

Bottom half-double: Put in a half-double scrim oriented to cut the bottom. Reply "Bottom half-double in."

Waste some of that: Pan or tilt the light so the hot spot isn't directly on the action.

Do off/on or A-B: Switch the light off and on so that the gaffer can observe what the light accomplishes. Announce "On" as you turn it on and "Off" as you turn it off.

Shake it up: With regard to a shiny board. As the sun moves, shiny boards have to be readjusted. The grips have to recheck that it is properly aimed. The phrase can refer to lights in the same way. Pan or tilt the light to make sure that it is aimed properly.

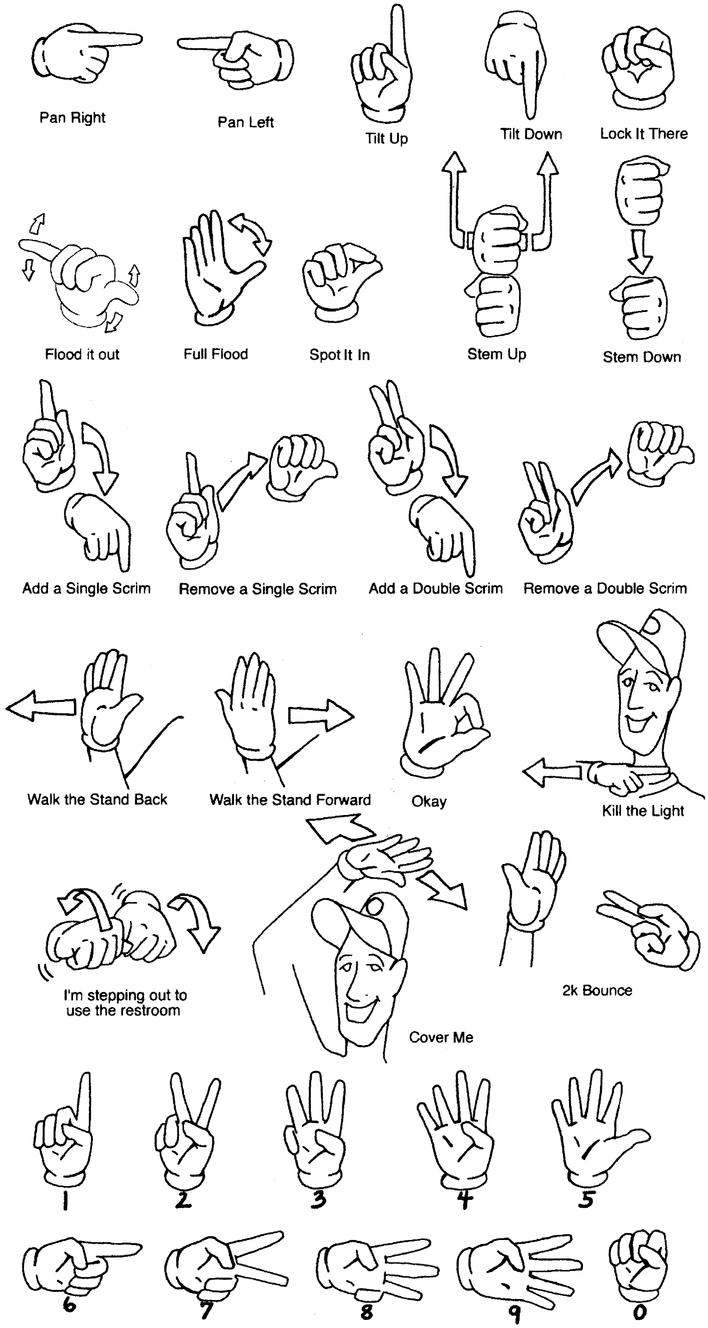

FIGURE 7.1

Hand signals.

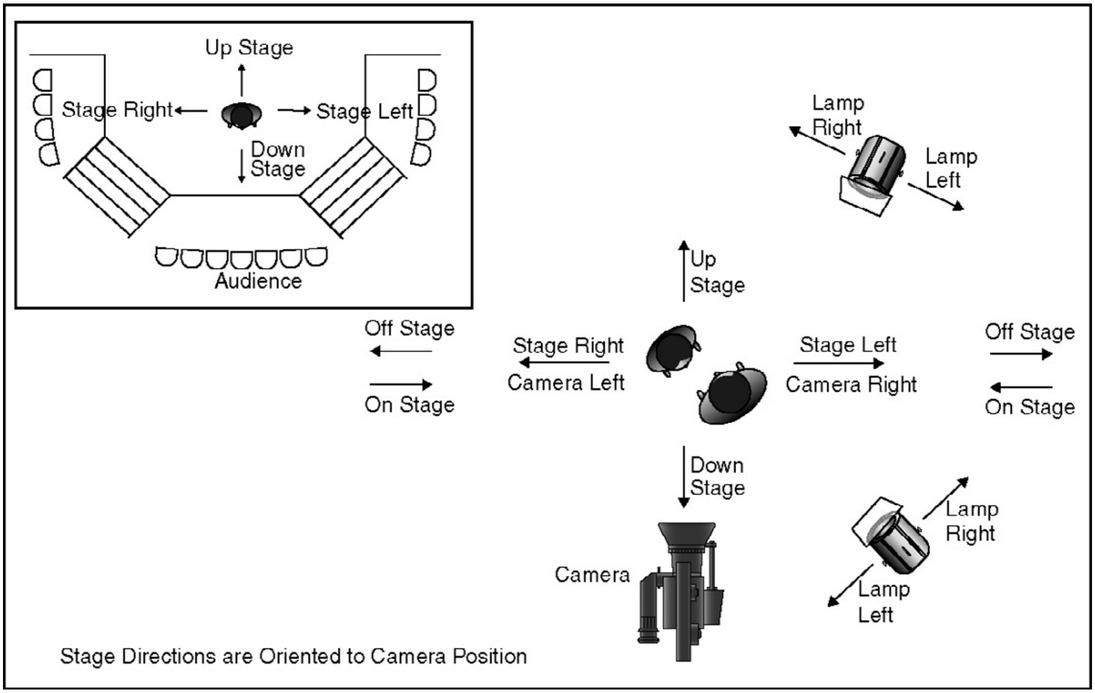

FIGURE 7.2

Stage directions are relative to the camera's position on a single camera show, or the proscenium on a multicamera show or stage performance. "Lamp" directions are just relative to that lamp, when the operator is facing the same direction as the light.

Flag the light: Pass your hand back and forth in front of the lens to show where the beam is hitting.

Give me a slash here: Bring the barn doors together to create a line where indicated.

Rotate the beam: PAR lights have an elliptical beam, rather than a round one. You can turn the lamp housing to orient the beam horizontal, vertical, or at any angle.

Dress the cable: Neaten up the cable or run it out of sight or out of the way.

Dress the light: Something is hanging off the light (i.e., a safety chain or diffusion is hanging into the shot). Clean it up.

Change that out for a deuce: Replace the light with a 2k fixture.

Count to 10: Hold off on what you are doing; things are changing and it may not be needed after all.

Cancel the baby: Yup, sure enough, we don't need that light.

Fire it up: Turn it on.

Cool the light: Turn it off. You also often hear, "Save the lights."

Strike the light: When referring to an HMI, strike means to turn it on, as in "Strike it up."

Strike the set: Take down all the lights and return them to the staging area.

It is customary for the electrician to respond to the gaffer's directions by repeating each direction back as he performs it. This assures the gaffer that she has been heard and someone is following her instructions. When she says, "Flood it out," the electrician responds, "Flooding" as he does so. When a delay is involved, he lets the gaffer know he has heard her before proceeding; if she asks for a light, the electrician responds, "Flying in" as he goes to fetch it.

Sometimes a gaffer and DP will try to sneak in some final accent lights while the director and actors are already rehearsing on set. The gaffer needs this to be done without drawing attention to what is being done. The electrician should be especially careful to focus and contain the light before turning it on and to work quietly.

Walkie-talkies

Walkie-talkies with earpieces or radio headsets are an invaluable tool for the grip and electric crew. They cut down the noise and the need to yell on the set, and save the electricians a lot of running. If you need something from the staging area and someone has just gone over there, for example, you can quietly ask that person to bring you what you need on the way back without yelling or running.

When using headsets or walkie-talkies, be sure to use proper mike technique: press the button fully, allow a second for the transmitter to engage *before* you start speaking and don't let up on it until *after* you have finished your last word. Otherwise, your first and last words will be cut short. When speaking, keep the mike about an inch from your mouth for a clear, strong signal.

Typically a walkie-talkie has many channels, which may be assigned to various departments. Usually, the assistant directors are on channel 1; the electric, grip, and transportation departments claim their own channels.

The gaffer initiates a conversation by asking for someone by name, "Dave, come back," or simply a general call for aid, "Electric", or "free hands". Respond with your name: "Go for Dave." Always acknowledge a transmission by saying "copy" or some similar response. If the transmission is interrupted by another transmission, say "You were stepped on, say again." If the signal breaks up during transmission, say "You broke up, come again" or repeat what you think the other person said and ask for confirmation. A broken signal is often an indication that the battery on the transmitting walkie-talkie is low and should be exchanged for a fresh one. Common usage has evolved to include various CB radio codes, such as:

Q: "What's your 20?" (Where are you?)
A: "I'm ten one-hundred." (I'm in the john.)

Use concise phrases. Brevity is the soul of wit, as Shakespeare said; try not to clutter up the frequency with rambling. If a lengthy explanation is unavoidable, you may want to change to an unused channel so as not to monopolize the frequency. Say "Go to 3" (or whatever channel is free). Then change to channel 3 and wait for a response. When the conversation is finished, say "Back to 5" or whatever the original channel was.

Last but not least, if you do not have an earpiece or headset and are operating with an open speaker, turn the volume on your walkie-talkie to 0 during takes, and remember to turn it back up again when the take is finished. Allowing your radio to blurt out, "Hey Dave, what's for lunch?" in the middle of a tense performance is what you might call a faux pas, and important people like the director and the actors are not likely to have much of a sense of humor about it.

Applying gel to the fixture

The most common way of attaching gel or diffusion to a Fresnel or open-face light is to clip it on with clothespins (Figure 7.3) or binder clips. Look out for light reflecting off the back of the gel and bouncing onto the walls of the set. Encircle the gaps in the barn doors with black wrap to block gel-reflection spill.

Don't be stingy with gel; cut a square of gel big enough that light does not leak around the side of the gel, causing spill. Placing the gel on the inside of the barn doors (Figure 7.3A) also prevents spill but puts more heat stress on the gel. Generally, this works well with Fresnel fixtures when they are flooded out. When using a dense gel, a particularly hot fixture (PAR or open face), or when the lamp is spotted, the gel is liable to lose color.

Gel frames can be used in some circumstances with some types of fixtures, but generally, the scrim slot is too hot a place for gel. Never put a scrim next to a gel frame. The hot scrim will melt the gel.

Safeties

When a light is hung above the set (suspended from the ceiling, set walls, or overhead pipes), a safety line should be tied around the yoke and around a permanent structural support capable of holding the weight of the light if it should come off its stud. The best type of safety line is aircraft cable, sometimes called a *dog collar* because it has a loop in one end and a carabiner or dog leash clip at the other. In the absence of aircraft cable, safety chain can be used. Be sure to leave enough slack in the safety line for the light to be panned and tilted.

Barn doors should also come with safety chain connecting them to the light to prevent them from falling. If a light does not have a barn door safety chain, use bailing wire or safety chain to attach the doors before hanging the light.

Lamp failure

When a lamp fails, be sure to label the light so that it isn't brought back onto the set by mistake. Put an X across the lens with 1-in. tape, and write *NG* (no good) or *BO* (burnt out) on it. If you know what is

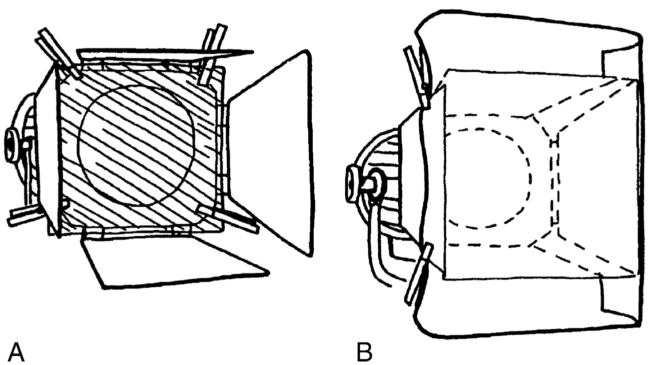

FIGURE 7.3

Gel and diffusion can be attached either inside (A) or outside (B) the barn doors.

wrong with the light, write that on it also (e.g., blown bulb, bad switch, bad plug). When a lamp fails the light is very hot, so the quickest course of action is immediately replace the entire head with a new one, rather than attempting to change the lamp. The lamp can be changed after the light cools.

Teamwork

It is important for each electrician to watch for a chance to back up another electrician. When a light is called for, one electrician sets the light, while another gets the power. When an HMI is called for, one person connects the head, the other connects the ballast. If a light is called for at the last minute, all the electricians work in a team: one person carries the head, another grabs a stand, and two more carry the ballast together, throwing the head cables over their shoulders. By the time the head is on the stand, the ballast cable is attached to the ballast and someone has run power to the ballast. The whole drill takes only a minute. The key to teamwork is communication and helping without getting in another person's way. Communicate. If you're running someone's power or fetching a gel for the person's light, be sure to tell that person so. By working together, a sharp crew can make the work that much easier and faster.

Warnings

When carrying large, heavy, or hot equipment through the set, call out warnings such as, "Coming through—watch your back" or "Hot points—coming through." You don't want to singe anyone's arm with a hot light. Ideally, one should be polite but firm, but "Duck or bleed!" also works pretty well.

When turning a light on, call out "Watch your eyes" or "Light coming on" before you hit the switch. This is a courtesy to the actors, stand-ins, and crew who are in front of your light. It is meant to warn them not to look at the light. It is a good idea to tilt the light up, away from the set, or put a gloved hand in front of the light as you turn it on. That way the light doesn't come on suddenly, and you give the actors or stand-ins a second to adjust to it before you pull away your hand. By the same token, the dimmer board operator brings lights up slowly on a two-second count; this is a courtesy to those in front of the lights at that moment, but also causes less stress on the lamp filament. This kind of courtesy is not just a matter of politeness but also one of professionalism. Similarly, avoid blinding people in general. If a working light needs to be moved, don't let it swing around and blast into people's faces.

If you are about to plug in a light and you can't tell if the switch is on or off, you can give the warning, "Possible hot stab." This is especially important if the light is aimed at someone or if the light coming on is likely to be an annoyance to the DP or gaffer. It is important to make a habit of turning lights off at the switch before unplugging them to avoid hot stabs.

Whenever a flash camera is used on the set, the photographer should call out "Flashing" before snapping the shot. This is mainly a courtesy to people in front of the camera, but it also alerts the electricians that a camera is about to flash. This way, the flash is not mistaken for a bulb burning out or an electrical arc.

PRACTICALS

In addition to all our movie lights, we also need to power and control (switch and dim) practical lights on set, and/or rig small bulbs into the set. Following is a brief description of some bulbs commonly required when lighting sets.

Photoflood bulbs and PH bulbs

Photoflood bulbs are color-balanced for use in photography (3200, 3400, and 4800 K) and come in various wattages, as shown in Appendix B. The 211 (75 W) and 212 (150 W) are often used in table lamps and suspended China-hat practicals. Higher-wattage photofloods are often used in soft boxes, Chinese lanterns, and scoop lights. Most photoflood bulbs burn very hot and have a short life, in order to provide the high color temperature. It is a good idea to preserve them by turning them off between takes when possible.

Household bulbs

A selection of low-wattage household bulbs (15, 25, 40, 60 W) is handy for making practicals glow without being overly bright. A household bulb's color temperature falls between 2600 and 2900 K, which appears yellow on film. In most instances, a warm color shift is appropriate for the scene (e.g., lamps naturally appear slightly warm), and the DP leaves it. If the color shift is objectionable, it can be removed with CTB gel (adhered to the inside of the lamp shade, for example).

Candella base bulbs

Some candelabra wall sconces and chandeliers take candella-based bulbs; this is something to check during location scouts. The bulbs, usually of low wattage, are warm in color. Round makeup table bulbs (40 and 60 W) are small, soft, very warm (2600-2700 K) bulbs that can be grouped to make an inexpensive, soft glow light.

Mushroom floods: R-40 and others

Flood- and spotlights of the mushroom-shaped variety incorporate a silver reflector inside the bulb for better output and throw. Common wattages are 75, 150, 300, and 500 W (EAL). 3200 K R-40 bulbs are available in 200, 300, 375, and 500 W wattages (see Table B.1). The rest fall between 2800 and 2900 K. The R-40 size is the most commonly used. A Lowel K-5 kit includes sockets, mounting bracket, and barn doors that fit snug onto the front of an R-40 bulb. There are a wide variety of other reflector bulbs. The number indicates the size; for example, in R-40/FL, R stands for reflector and 40 is the size (in eighths of an inch: 40/8 = 5 in.). FL indicates flood. Smaller R-30 and R-20 bulbs are great for track lighting or lighting wall art at close range.

MR-16

MR-16 bulbs are tungsten halogen projector bulbs with a 2-in. parabolic reflector. They are available in various color temperatures including 3200 K. Now commonly used in track-lighting fixtures, they come in a variety of wattages, voltages, and reflector types. The VNSP MR-16, which has a mirrorlike parabolic reflector, makes an amazingly bright narrow column of light. The tiny size, brightness, and color temperature of MR-16s make them very useful bulbs for making small pools of light. You'll find more about MR-16 lamps including a number of useful accessories in Chapter 3.

Linestra tubes

These are incandescent, tube-shaped bulbs 12, 20, or 40 in. long and ¾ in. in diameter. Their color temperature is 2800 K. They are very lightweight and can be attached with tape or bailing wire. They are used in sets, lighting shelving, for example.

Controlling practicals with dimmers

It is standard practice to put all practical lamps on dimmers so that their intensity can be easily adjusted. This may be done by connecting them to a dimmer pack or rack through the distribution system and controlling everything from a control console, or by plugging them into a small residential dimmer connected to hard power on set. When using dimmer circuits from a pack or rack, label each practical with the circuit number. A small neat lable made with a p-touch printer and adhered right to the sconce or practical lamp base, will be invisible to camera, but easy to read on set.

Residential 600 or 1000 W dimmers are commonly used for dimming practicals. This type of dimmer employs a triac circuit, which uses a simple method of forward phase control to vary the RMS voltage. For incandescent lamps that operate at 120 V, a standard residential dimmer works just fine. However this type of dimmer is not necessarily approved (designed, tested and UL-listed) for powering any load that has its own transformer, power supply or ballast. In order to control these kinds of loads dimmer manufacturers have developed specialty dimmers.

Type of load	Type of load	Compatible dimmer
Incandescent/halogen lights	Resistive load	A normal residential dimmer is a triac. It uses forward phase control dimming, the same principal as the SCR dimmers discussed in Chapter 13. They are rated for cold inrush current associated with filament lamps. This type of dimmer may not use symmetric duty cycles.
Magnetic transformer for low-voltage (MLV) lighting (6, 12, or 24 V)	Inductive load	This dimmer uses forward phase control also, but the cycles are symmetric and each duty cycle has a smooth turn-off characteristic.
Electronic (solid state) transformer for low-voltage lighting (ELV)	Capacitive load	The dimmer uses reverse phase control for a smooth turn-on. This type of dimmer connects to the neutral in addition to the hot lead.
Neon and cathode tube ballasts	Very inductive loads	This dimmer uses forward phase control, but the cycles are symmetric with a smoothed turnoff. This type of dimmer also features low-end trim capability.
Fluorescent: electronic dimming ballasts	Not dimmed via input voltage	These dimmers work by sending a control signal to a compatible dimming ballast, which then regulates the drive current to the lamp. The input voltage to the power supply is constant.

Source: Lutron residential dimming product information. SCRs and phase control dimming is described in detail in Chapter 13.

Other ways to control practicals

There are other ways to dim a bulb that do not alter the color temperature. Spraying the bulb with a light speckle of black streaks and tips is a fast way to reduce the bulb's intensity. (Don't spray a hot bulb; it will burst.) Sometimes you want to reduce brightness in only one direction. This can be done by spraying one side and not the other. Holding a lighter close to the bulb and letting the carbon

build up on the bulb is another good way to dim it. The carbon wipes off more easily than streaks and tips. Placing diffusion on the inside of the lamp shade and installing ND gel around the bulb are also ways to dim a practical. Of course, you can also just use a lower wattage bulb to avoid having to dim the light.

Wiring small fixtures

Practical lamps

On any interior set, the art department will provide *practical fixtures*: table lamps, wall sconces, floor lamps, desk lamps, china hats, fluorescents, chandeliers, and so forth. Each time you begin working on a new set, one of the first things to take care of is the wiring and testing the practicals and changing the bulbs as desired by the gaffer.

Lamps and sconces often come from the prop house with bare wires and typically need to be fitted with a cord and plug. When adding a tail to a light fixture, extra-hard usage cable is required. Use wire nuts to insulate wire splices and house the splice inside the base of the fixture, or inside an approved electrical box. If a lamp or sconce is metal and not UL-listed, a grounding wire is required. UL-listed lamps may use 18/2 power cord up to 6 ft. long, provided that the cord is consistent with the lamp's original design.

In the past, 18/2 zip cord, add-a-taps, and quick-on plugs were often used for wiring small fixtures; however, the National Electrical Code and all the major studios require the use of "hard usage" or "extra hard usage" cord on sets and locations used for filming, so zip-cord, which is "junior service" cable, does not qualify. Junior sevice cords are prohibited because it poses a potential safety hazard. A long run of zip cord imposes so much impedance in the cord that a dead short may not trip the circuit breaker. The cord can potentially burn up before it will trip the circuit protection, which is a serious fire hazard. Zip cord is rated for 10 A maximum and will not withstand overamping.

Practical outlets

A well-made set has *practical wall outlets*. These are very convenient for plugging in practical lights, and lights. The outlet must be housed in a standard UL-approved outlet box. On the outside wall, the outlet box usually has a short tale (of extra-hard usage cable) with an Edison plug. This can then be connected to a distro box, or dimmer circuit. Again, label any dim circuit with a small p-touch label.

Wiring plugs, sockets, switches, and connectors

When wiring or repairing electrical devices, be sure to *make as solid a connection as possible*, bringing together as much surface area of copper at each terminal and making each terminal tight and secure. Plugs, sockets, connectors, and switches are the weak spots in a circuit. They create resistance that can eventually heat up the wires, which further degrades the conductors and their insulation, further increases resistance and heat, and eventually poses a fire hazard, or simply causes a nuisance by burning out.

Also for safety reasons, any time you install or replace a switch or connector, *pay attention to the proper polarity*. On plugs and sockets, the gold terminal is for the hot (black) wire, and the silver

terminal is for the neutral (white) wire. The green terminal is for the green grounding wire. If an electrical device is connected with reverse polarity, the neutral and hot wires are reversed, and a potential safety hazard exists. The switch controlling the fixture, which normally interrupts the hot wire, now interrupts the circuit on the *return* wire (neutral). Although the switch still functions, it has a hot lead running to the lamp when turned off—a hot lead looking for a place to ground. So, even though the fixture is off, it is still *hot*. For example, someone attempting to change the bulb, thinking that because the switch is off the light is safe, could be in for a jolting surprise. This is precisely why one should always unplug a fixture before putting a hand inside it, even if the switch is off. When installing a switch, *a single-pole switch must be connected on the black wire*, not the white.

Double-pole switches and three- and four-way switches

For 240 V circuits and lights 2k or more, it is necessary to have a switch that interrupts both wires at once. This is known as a *double-pole* switch.

It is sometimes handy to have two or more switches in different locations to control a circuit. To do this, wire two three-way switches. When more than two switches are needed, a three-way switch is connected at the beginning and end of the chain of switches, and any number of four-way switches can be connected between them. In either case, any of the switches will close and open the circuit, regardless of the position of the other switches.

STINGERS AND CABLING

A set can quickly become a rat's nest of tangled cables if care is not taken when running cables and stingers. Here are some guidelines.

Circuit balance and capacity

The best boy electric and/or generator operator is generally responsible for monitoring the balance of loads on the cables. Each electrician must know the cable layout, know where to find power drops, and keep tabs on the amperage on circuits that are operating near capacity. When balance (between phases) or circuit capacity is critical, keep the best boy abreast of new lights being added. With large lights (5k or larger), consult with him as to which circuit should be used before plugging in. When the phase wires are drastically out of balance, the load must redistributed. Repatching one or two well-chosen lights from the high phase to the low phase can usually balance the loads. Keep in mind that when you are using dimmer racks, it is often easiest to repatch at the rack.

It is normal for cables to run warm, but if they become hot to the touch, replace cables as necessary and notify the best boy electric.

If a fuse blows repeatedly, something is wrong. The circuit could be overloaded, in which case the problem will be solved by redistributing the load onto other circuits. There could be a short in a light, a plug, or an outlet. The short can be found by isolating the items plugged to the circuit. Mark the bad part with an X, mark it "B.O." and take it out of service and hand it off to the best boy to repair or replace.

2k Plugging policy

To help other electricians know which duplex outlets are maxed out and which still have amperage to spare, make it a policy within the department to always plug a 2k lights into the top duplex outlet. If you are plugging a 1k or smaller use the bottom outlet first. This way, any electrician knows at a glance which duplex outlets have capacity to spare and which are already maxed out. It is also helpful to label the plug of 2k lights so that you can identify them among the many cords at the outlet box, and keep them on separate 20 A circuits.

Cables crossing the set

Keep cables out of the shot and out from underfoot. An electrician rarely runs a cable in a direct line from power to light. Before running the cable, consider the best way to run it. Avoid crossing doorways, especially if there is a chance that the door will work in the scene. Run stingers around the edge of the set. Gaffers often say that you can tell a good electrician by the cable you *can't* see. The most convenient setup is to have the distribution cables run above the set with power drops in strategic locations. This eliminates a lot of cable running around the set.

Cables crossing work areas

When cable has to cross an area where there is foot traffic (a hallway or doorway), use cable crossovers (Figure 7.4) or put a rubber mat over the cable and tape it securely to the floor with wide gaffer's tape.

If there is a danger of people tripping on the bulge of the mat, put diagonal stripes of yellow tape across it so that it will be noticed. When cables cross an area where vehicles or carts will be moving, protect the cables with cable crossovers. HMI cables especially should never be left vulnerable. Another way to protect cable from damage from wheels and foot traffic is to lay 2-in. × 4-in. lumber on either side of the cable and tape it down to the floor.

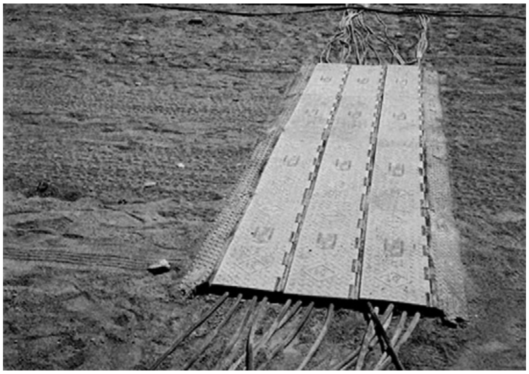

FIGURE 7.4

Cable crossovers protect cable from traffic, and protect pedestrians from tripping or rolling on cables.

(Courtesy of Yellow Jacket, Inc.)

Appropriate length

Use an appropriate length stinger to reach the light. A *clothesline cable,* one that is taut and off the floor, is an accident waiting to happen—someone is sure to trip on it. Stingers normally come in lengths of 25 and 50 ft. A rule of thumb for fast identification is: a 25-ft. stinger has about seven coils and a 50-ft stinger has roughly 14. When a light is on a stand, the power cord should fall straight to the ground at the base and have some slack coiled or in a figure-eight at the base. Keep excess cable coiled neatly. Place the coil such that if the stand is moved, the cable will play out from the top of the coil, not from the bottom.

When lights are hung from pipe, be sure to leave two loops of slack cable hanging at the light. If the light later needs to slide down or pan around 180°, you need slack to play with. Run the power cable down the pipe to the service or to the end of the pipe. Tie it to the pipe at intervals with mason line or sash cord. Never wind a cable around a pipe; this makes it impossible to move later, and a hassle to remove at wrap. Remember: "Rig to wrap."

Preventing "kick-outs"

When connecting two cables, tie a strain-relief knot to prevent the connection from being tugged apart (Figure 7.5). This helps prevent a "kick-out" (accidental unplugging). In the event of a kick-out or "gap in the line," the electrician must quickly track down the culprit connection. As with everything else on the set, remaining aware of what is happening around you will help you spot kick-outs immediately. Note for cables with delicate connectors such as DMX512 control cables, tie the strain relief so that there is no bend or stress at the connector, using the method shown in Figure 7.5C.

Repatching

You will sometimes need to unplug a light that is in use to replace a cable, run power from a different direction, or readjust the loads of various circuits. Before you unplug the light, inform the gaffer

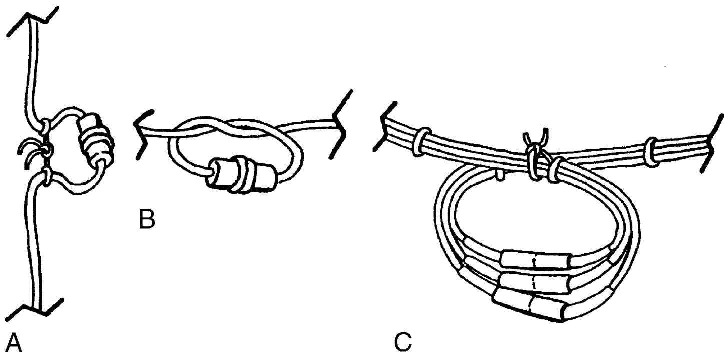

FIGURE 7.5

When there is danger of an accidental kick-out, use a strain relief. (A) A dangling connection held with the tie ropes, (B) a simple strain relief for a stinger running along the ground, (C) banded cable connection point.

of the need for a repatch, and as you disconnect it, call out, "Repatch." This assures everyone that the light has not gone out accidentally. Frequent repatches can be irritating for the gaffer and DP. In many situations, it may be best to find another way to solve the problem.

The gak package

Accessorize each distro location. Next to each distro box (600, 900, 1200 A, or what have you), a selection of appropriate extension cables and adapters should be stowed. For example:

- 2 50-ft. 100 A Bates
- 2 50-ft. 240 V 100 A Bates (when 20 ks or other 240 V loads are being used)
- 2 100 A lunch boxes
- 2 milk crates containing:
  - 4 25-ft. stingers
  - 4 50-ft. stingers
  - 2 100-60 A splitters
  - 1 100-100 A splitter
  - 1 100 A gang box

To streamline the process of powering lights as they are added, have at least two stingers standing by at each power drop or gang box, coiled and ready for use.

Labeling stingers and power cords

Labeling cables helps immensely in identifying problems and recabling lights when needed. When a cable runs out of the set through a rat hole, over the top of the set, or up into the pipes or greens above the set, both ends of the cable or stinger should be labeled with tape. Indicate the lights it is powering—for example, "2k window light" or "stair sconces." Similarly, when using a dimmer board, the gang box or female receptacle of the power cord should be marked with the channel number. See Chapter 15 for notes on labeling and laying out distribution equipment.

When lights are hung from a grid, it is helpful to be able to identify each light by number. Label each light so that the number is visible to the gaffer on the ground below. Write the numbers large and legible on 2-in. tape on the underside of each unit. Mark the tails (the plugs) with the same numbers. With the lamps numbered, it is easy for the gaffer to communicate what he or she wants.

Labeling dimmer settings

When setting a dimmer level, start with the dimmer at line voltage. Say, "Line voltage." The gaffer may then specify a setting to try, by saying "Set it at 90%" or just say, "Lower,. . . lower. . . lower, good." Keep replying with the level, "That's 80. . . 70. . . 60." Once it is set, make a mark on tape to indicate the setting. If several settings are used, number them. After the shot is completed, leave these markings on the dimmer until you're sure that they won't be needed again.

Lights on SCR dimmers will buzz at certain dimmer settings. A quick solution when the sound personal find this a problem, is to repatch the light into a variac dimmer.

Coiling stingers and cable

All cables and stingers are coiled clockwise. Each loop puts a twist in the cable. When uncoiled, it must be allowed to untwist, or it will start to twist onto itself.

The stranded copper wire inside a cable has a natural twist; coiling counterclockwise works against the grain. When a cable is consistently coiled in the same manner each time it is used, the cable becomes "trained" to coil that way. A trained cable coils easily. If a cable is coiled different ways with each use, it becomes confused and unmanageable.

The over/under method shown in Figure 7.6 is used for coaxial cable, dimmer control cables, and audio cable. Every other loop counteracts the twist so that the cable can be unraveled without twists. Using the occasional underhand loop sometimes makes a cord more cooperative.

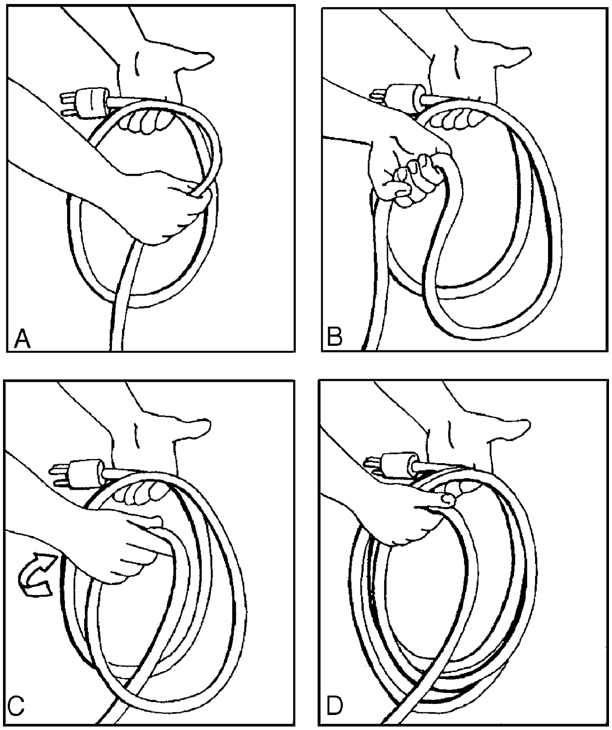

FIGURE 7.6

When you coil a stinger, use your wrist to put a slight twist on each loop; the stinger will coil easily. When a cable wants to twist too much, you can use the over/under method of coiling. Always use this method with control cables: (A) start with a normal loop; (B, C) give the second loop a twist to the inside; (D) make the next loop normal. Alternate back and forth between a normal loop and a twisted loop.

SAFETY

You don't have to work on sets long before you see that in a rush, people can forget to use their common sense. This is how people get hurt and equipment gets broken. Make safe work practices habitual and you will avoid needless injuries, especially when working under pressure. Work swiftly but never run.

Various organizations provide codes, standards, and regulations aimed at protecting employees in the workplace, including studio safety departments, the Industry-Wide Labor-Management Safety Committee, federal and state Occupational Safety and Health Administration (OSHA), and others. A comprehensive guide to safety organizations, codes, and standards is available on the *Set Lighting Technicians Handbook* Web site.

Ladders

When working with suspended lights, you must often work from a ladder. If the ladder seems at all shaky, have someone hold it and spot you at the bottom of the ladder. Use the appropriate size ladder. Don't use the top two steps. Don't stretch to reach a light that is too far from the ladder; instead, get a taller ladder, or climb down and move the ladder.

Two people often need to work from two sides of the same ladder when rigging two lights very close together. When you step onto someone's ladder, say "On your ladder," and when you step off again, say "Off your ladder."

Parallels

Parallels are quite frequently used as a lighting platform. They are quick and easy to assemble and, if used with proper caution, can be safe. However, "caution" is the watchword. Almost any veteran electrician can tell you a story about an accident involving parallels.

Parallels must be set on level ground or be leveled with leveling jacks. On uneven ground, it can be hard to tell what is level; a plumb line or bubble level should be used. A leaning parallel is an accident waiting to happen. Be sure that weight is distributed evenly on the platform, especially when lifting equipment up to the platform. Never mount lights outside the perimeter of the railing. Use a ladder to get up onto the platform.

Large light stands should be strapped down to the platform. Ratchet straps and nylon webbing are ideal, although chain or rope can do the trick if properly used. Remember to take into account the force of the wind blowing on 4-by frames. Tie guy lines to the bail or stand when needed. Tie the power cable to a vertical post on the platform, leaving plenty of slack to maneuver the light.

Working aloft

Anytime you work at a height—on a ladder, greens, catwalk, parallels, or truss—remove your tool belt. Tie any tools you need to your belt. Dropping a tool from the catwalks could seriously injure or even kill a person below. Dropping objects from the catwalks is a serious safety violation, and doing so can get you kicked off a studio lot.

Remember to bring a tag line so that you can hoist equipment as you need it. The tag line should be tied off at the top end so that it cannot fall. Call "Line out" before you toss down the line.

Protecting floors

Protecting the floor becomes a concern when shooting in a set where the floors might be scratched by metal stands, especially on location. A number of precautions can be taken. One is to put crutch tips on the feet of each stand. Tape the rubber tips in place with electrical tape. A stock of crutch tips should be ordered in advance after the location is initially scouted.

Layout board (hard cardboard that comes in 4-ft. × 8-ft. sheets) can provide a protective covering over the floor. It is usually laid out over the entire area and taken up wherever it will be seen in the camera's frame. A more temporary substitute is a furniture pad placed under the stand.

Sprinkler systems

Placing a hot light too close to a sprinkler head can easily melt the soft alloy valve that normally holds back the flood. There is no way to stop an activated head from flowing once it has started, and the water in the pipes will continue to drain for hours, even if the sprinkler system is immediately turned off at the source. With the fire marshal's permission, make a practice of putting Styrofoam cups over sprinkler heads to insulate them from the heat of the lights. In the category of big blunders, few are more conspicuous than activating the emergency sprinkler system and dousing the actors and sets in water. Provide adequate clearance from walls, ceiling, and surfaces. Remember to remove these after wrap, as this could prevent the sprinklers from operating when they should, which is a major liability.

Smoke, fire, and other bad smells

Lights get very hot and can easily start a fire. Common sense and proper care are essential to the prevention of accidents. If a curtain is blown by the wind it could blow onto a nearby light. If there is debris flying in a scene, precautions should be taken to prevent it blowing onto the fixtures. This is especially important when fixtures are unattended. In the event of a small fire, a quick electrician may be able to smother the flames with gloved hands or with a furniture pad. Know where the fire extinguishers are.

An electrician with a good nose and good eyes can detect a potential fire before it becomes serious. If you smell smoke, don't cause a panic, but let the other electricians and grips know so they can help look for the source. The smell of burning wood may be caused by a toasting clothespin or a light placed too close to a wooden set piece. The smell of burning plastic or rubber may be traced to smoldering insulation on a cable connection or inline switch. An overheated stinger is a common offender. Check the lights for burning gel or diffusion and smoking flags or nets. Check the set walls and ceiling for bubbling or smoldering paint. Keep looking until you find the source of the smell. The problem may be something obscure, such as burning bakelite plastic in a defective deuce board (an older type of distribution box with remotely controllable contactors).

A smoking light is usually the result of some foreign matter getting into the light and burning up. Dusty lights often smoke for a short time when they are first turned on. Moths are relentless

kamikazes. They will keep an open-face fixture smoking all night as they bake themselves one after another. Outside in a ventilated area, this does not pose a danger to anyone but the moths. Inside, though, it may be necessary to turn off a smoking light and clean it out. Sometimes the only way to clean the light is just to let the substance burn off.

AERIAL LIFTS (CONDORS AND SCISSOR LIFTS)

There are a variety of types of aerial lifts commonly used as platforms for lights and lamp operators: a straight mast boom (Condor), articulated boom (knuckle boom), scissor lift, and man lift. Aerial lifts are invaluable tools, both on the sound stage and on location. With the right lift, riggers and lamp operators can move easily into hard-to-reach places to hang and adjust lights and cable.

The standard moonlight rig for night time street exteriors consists of one or two large lights mounted to the basket of a telescoping straight mast boom, raised over one end of the street. Condor, Snorkelift, JLG, Genie, and Simon are the dominant makes, but *Condor* is the common name for a straight mast boom. An electrician is designated to operate the platform and the lights mounted on it. Productions often need to bring on an extra hand for "Condor duty," so knowing how to operate an aerial lift can get your foot in the door with different crews.

Lighting technicians must receive training and gain some experience operating aerial lifts before accepting such work. One has to learn how to inspect the aerial lift, what to check for, how to operate the controls, how to level the lift. Equally important, one needs to learn how to load and operate the lift so that it remains within the manufacturers' specifications. Rigging and cabling a condor also requires some know-how. A complete description of aerial lift operations is available at the *Set Lighting Technician's Handbook* Web site.

THE WRAP

When filming is completed at a given location, all the equipment has to be packed back into the truck. This may take an hour or two when a lot of equipment is in use. Especially after a long day, it is everyone's dearest wish to get the truck packed as quickly as possible and get home. One of the best boy's responsibilities is to begin the wrap early and have as much of it done as possible before the actual wrap is called. Early in the day, the best boy organizes the removal of superfluous equipment from the set and the coiling of cable no longer needed. Once the last setup is lit, on the gaffer's word, any equipment not in use can be stowed and ready to drive away.

When wrap is called, lights are switched off and the equipment starts coming back to the truck. I find that it works best if the best boy remains at the truck and packs the equipment as it is brought to the lift gate by the electricians. This avoids equipment piled up at the gate. Wrapped lights should look like the one shown in Figure 7.7. The bail is swiveled up over the top of the light. The power cord is coiled, tied, and hung over the bail or tucked under the bail. The barn doors are shut. Scrims, diffusion, and gel have been removed and returned to the scrim and gel boxes. Spreader lenses are removed from PAR lights. The globes should be removed from larger lights (12k and 18k HMIs) before travel.

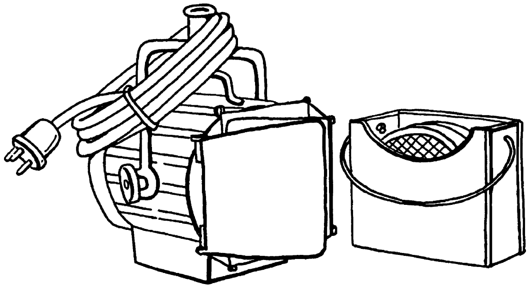

FIGURE 7.7

A properly wrapped light. Some electricians prefer to tuck the cable inside the bail to prevent it from getting caught on other equipment.

Coiling feeder cable

The fastest way to coil feeder cable (banded, 2/0, or 4/0) is to stand with your legs apart and coil in a clockwise circle on the ground. With a little practice you can get into a rhythm, pulling the cable toward you with one hand, then the other, guiding it into a coil. If you are fighting the natural twist of the cable, the coil will not want to lie flat, and the unnatural twist will age the cable. The ideal size for a coil is tight enough that the finished roll is not floppy and unmanageable, but not so tight and tall that it becomes impossible to stack. Use the tie strings to secure both ends firmly. Loose ends tend to swing around, hit people, and generally get in the way. Lift with your legs, not with your back.

Inventory

The best boy conducts an equipment inventory during loading. If each cart and truck shelf has been labeled with the type and quantity of lights it holds, this process is quite straightforward. Strap off each shelf as soon as it is complete; this helps keep track of what is still missing; and once all the shelves are filled, the truck is ready to go without further delay. Putting each light in its proper place is not just a matter of organization—it can be crucial to fitting everything on the truck. Before leaving any location, one of the lighting technicians should run an idiot check on the set, looking in each area where lights were placed during filming.

CHAPTER

Light fixtures: The HMI arsenal

8

METAL HALIDE ARC LIGHTS: "HMI"

Unlike a filament lamp, a metal halide arc lamp, commonly know as an HMI,[1] generates light by creating an electrical discharge between two electrodes held a short distance apart from one another within a quartz envelope. The lamp produces a color spectrum of daylight-balanced light—5600 or 6000 K, depending on the globe manufacturer. Manufacturers have developed a full range of light fixtures that use metal halide arcs lamps, including: Fresnel fixtures, pars, beam projectors, follow spots, open-face lights, softlights, moving lights, ellipsoidal spot lights, lantern lights, underwater light, and small battery-powered sunguns, as well as other unique fixtures. Tables listing useful specifications for HMI fixtures are available on the *Set Lighting Technician's Handbook* Web site.

Daylight-balanced lights are indispensable in a number of scenarios:

1. When shooting daylight exterior scenes, the artificial light needs to mix with natural daylight. This is equally true when shooting an interior scene that has lots of windows.
2. When shooting with daylight-balanced film.
3. When shooting tungsten-balanced scenes that require blue light, such as "moonlight."
4. When you need big lights. An 18,000 W HMI light is much, much brighter than even the largest tungsten source.

An HMI puts out almost four times as much light as a tungsten light of the same wattage, 85-108 lumens per watt of electricity, compared to 26-29 lumens per watt for tungsten halogen bulbs. This is partly because an incandescent bulb expends 80% of its energy creating heat (infrared wavelengths), whereas HMIs convert that same percentage of its energy into usable illumination. As a result, the beam of an HMI is not as hot as the tungsten equivalent. HMI light fixtures are also able to focus the light from the small arc source more efficiently than can be done with a relatively large tungsten filament.

The color spectrum of a metal halide arc is not continuous, but comprises many lines that constitute a fairly complete spectrum. Figure 8.1 shows a typical multiple-line spectrum. The HMI lamps we commonly use have a Color Rendering Index around 95. (Metal halide arc lights such as MSRs used in moving lights can have a somewhat lower CRI. See Chapter 11).

[1]HMI is the registered trade name of Osram for its discharge lamps; however, HMI has become the common name referring to discharge lamps of this type, regardless of manufacturer. The many other manufacturers and trade names are listed later in this chapter.

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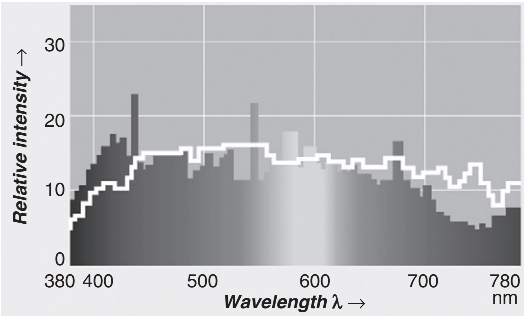


FIGURE 8.1

HMI lamp spectral power distribution. The white line represents the spectral distribution of actual daylight in Europe. The gray area shows the spectral distribution of an Osram 18 kW SE lamp. A multi-line spectrum shows a series of peaks distributed across the spectrum. These combine to make a reasonable approximation of daylight, with a high color rendering index of 95.

(Courtesy Osram Corporation.)

An HMI light uses a ballast connected between the AC power source and the lamp head. A ballast is a power supply that regulates the power to the lamp head, and powers the igniter circuit to initiate the arc. An HMI therefore has the following component parts: the head, the head cable, the ballast, and in most cases a separate ballast cable (Figure 8.2). With the exception of the battery-powered systems described later, HMIs run on AC power only, and they cannot be operated on a dimmer line. There are two types of ballasts: *magnetic*, the original type of power supply, and *electronic* (also called *square wave* or *flicker-free*), which are more common these days. Electronic ballasts can dim an HMI to 50% output. They cannot be dimmed below 50%, because the arc becomes unstable. Electronic ballasts can also be ordered with DMX512 control to provide 50% dimming and on/off control from a lighting control console. There are some important operational safety and performance limitations that one must be aware of when using HMIs. We will discuss camera speed limitations and UV protection in later sections of this chapter.

HMI fresnels

The most common types of HMI fixtures are Fresnels and PARs. As with tungsten lights, the Fresnel's lens/reflector assembly allows fine adjustment of the beam angle. The lens imparts a very even field with nicely feathered edges that make it easy to blend lights. The beam is easy to cut and shape with barn doors or grip flags. Small Fresnels of 125, 200, 575, and 1200 W are commonly used as interior direct light or bounce light when daylight color balance is needed. They are equivalent in size and function to a tweenie, a baby, and a junior, respectively. These sizes have the advantage of plugging into a standard household outlet when necessary.

Medium-size HMI Fresnels of 2500, 4000, and 6000 W are used in much the same manner as 5k and 10k tungsten units—to light large interiors, to double as sunlight, to provide fill on exteriors, or to provide key light and backlight on night exteriors, just to give some examples.

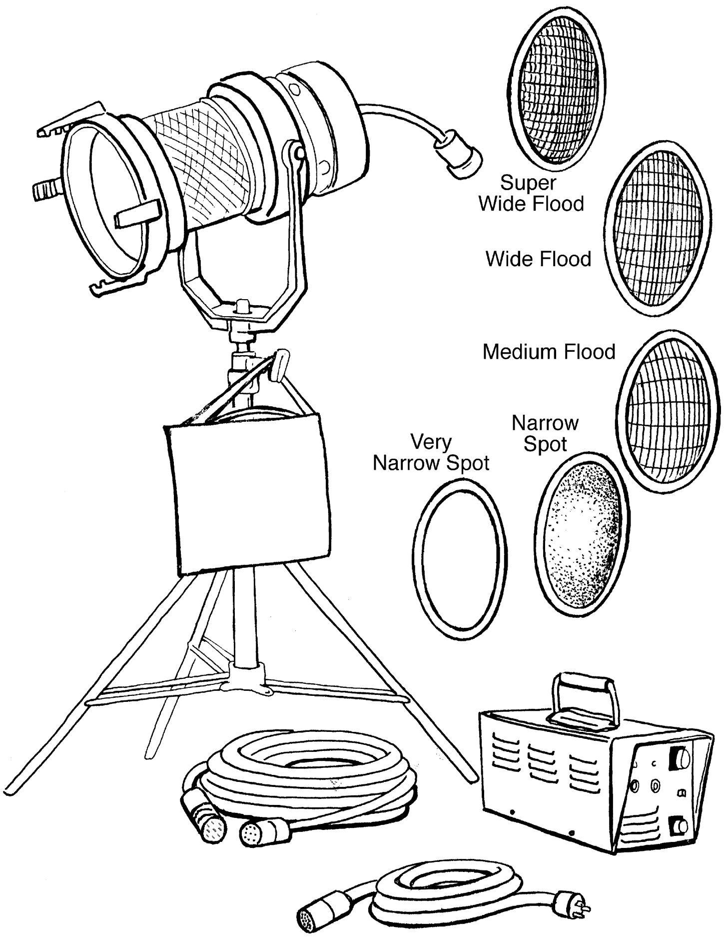


FIGURE 8.2

1200 PAR head, head cable, ballast, ballast cable, scrims, lens set (lens case and second head feeder not pictured).

The work of the large HMI Fresnels, 12k, 18k, and 24ks, was once the domain of the iconic carbon arc light. When you see sunlight streaming in through windows in a movie, odds are good that an 18k Fresnel or two are sitting outside on the lawn (Figure 8.3). These are real workhorses in film lighting and are a necessary part of almost any equipment package. They are used for fill on day exterior shots or to cover wide exterior night shots from great distances. One or two are very often mounted to an aerial lift (Condor) to light up a city block from high up in the air. They may be put through diffusion or bounced to create a large, bright soft source.

FIGURE 8.3

A line of 18 kW HMI Fresnels surround a tiki hut.

(Photo courtesy Mike Bauman.)

The original design of HMI Fresnels used double-ended lamps. By the mid-1990s, single-ended HMI lamps became available. The single-ended lamps offered many advantages and improved the optical train of HMI Fresnels. Both types are still in common use.

Even larger HMIs, 24 kW and even 36 kW, are in development. The first 24 kW HMI Fresnels became available on the market in 2009 (Figure 8.4). The Power Gems ballast draws about 122 A per phase, so the ballast has to use cam-loc (or other) connectors. Special distribution equipment is available from Mole-Richardson and others, which provides cam-loc connectors protected by 125 A circuit breakers. It is critical with these high currents that the voltage to the ballast be correct. The lower the mains voltage, the higher the current necessary to maintain lamp power. If voltage-

FIGURE 8.4

24 kW HMI Fresnel.

(Courtesy Ron Dahlquist, Dadco/Sunray MFG.)

drop in the distribution cables is too severe, the ballast will shut down and give an "under-voltage" message. It is designed to do this to protect itself from excessively high current.

The 24-kW lamp uses a higher voltage than the 18-kW lamp. The Power Gems 12/18/24 kW electronic ballast is auto sensing—as soon as the lamp is struck, the ballast automatically senses the presence of a 12-, 18-, or 24-kW lamp. Because the lamp voltage is higher, the current through the head cable is roughly the same as that of an 18 kW light, so the 24-kW head and 18-kW head can use the same head cables.

HMI pars

Par lights are more efficient than Fresnels, though the beam is less even and refined. Pars are designed to deliver a strong punch of light with a longer throw (Figure 8.5). The beam spread is adjusted by inserting a spreader lens at the front of the fixture. The original 1200 W HMI lamps were built like a PAR 64, with bulb, reflector, and UV lens all in one sealed unit. Today's HMI par lights use a single-ended HMI globes, enabling the full range of wattages up to 18 kW. The lamp is axially mounted in the fixture in front of the highly efficient parabolic reflector. UV-protective glass covers the front of the unit.

HMI pars come in sizes 125, 200, 400, 800, 575, 1200, 1800 W, 2.5k, 4k, 6k, 12k, and 18k. The 1200 W and 4k pars are the two most used of all the HMI units. An 1800 W lamp was introduced in 2009—this is small enough to be plugged directly into a 20-A wall outlet when used with a power-factor-corrected electronic ballast. In combination with a very efficient reflector, ARRI's 1800 W par competes with 2500 W pars in intensity. This fixture can use either a 1200- or 1800-W lamp.

FIGURE 8.5

Axially mounted, single-ended HMI lamp in a 2500-W PAR housing. Star-shaped lamp-lock knob is visible.

(Courtesy LTM Corporation, Los Angeles, CA.)

The 1200-W/1800-W auto-sensing ballast is specially designed to remain below the 20-A breaker current threshold. When mains voltage is low, an electronic ballast draws more current in response, but this ballast incorporates a limit to avoid nuisance breaker trips.

The spreader lenses affect both the shape and angle of the beam. For example, for a typical 1200 W PAR, the very narrow and narrow spot lenses give a circular beam of 6° and 8°, respectively. The medium and wide flood lenses give a wide elliptical beam of 27° × 11°, and 60° × 25°, respectively. The super wide flood gives a circular beam of about 54°. To turn an oblong beam, the operator rotates the lens. On ARRI fixtures, there are actually two kinds of lens sets. The smaller snap-in lenses provide maximum optical efficiency, because the lens is positioned directly at the front of the fixture, right up against the edge of the housing where the ARRI engineers intended. However, this position is extremely hot and electricians know that it is far easier to use the larger drop-in lenses that simply fit into the ears. The engineers at ARRI no doubt wring their hands over this needless loss of 10-20% of painstakingly engineered optical efficiency, but they are not the ones who have to endure burn scars on their forearms.

During the evolution of HMI fixtures some manufacturers created lights that could take either a 2.5k lamp or a 4k lamp. Because 2.5 and 4k lamps have different lamp center lengths (LCLs), it was necessary to provide a way to move the lamp forward or backward in relation to the reflector to position the arc at the focal point of the reflector. Providing this adjustment inadvertently turned the par light into a "focusable" unit—a feature DPs and gaffers found very handy. When used with spreader lenses, the spot/flood functions best as a focusing adjustment to smooth out the field. The adjustment for a smooth field differs depending on the lens in use.

12k and 18k pars

The optical efficiency of the largest HMI pars—12k and 18k fixtures—make them the most powerful of all the HMIs. They are more compact and lightweight than the large Fresnels. A Molepar 12k/18k head weighs 67 lbs (by contrast the Mole 12 kW/18 kW Fresnel head weighs 150 lbs.) so it would be possible to mount several of them onto the basket of a condor without exceeding weight specifications. 12k and 18k SE par fixtures are ideal for re-creating sunlight. Figure 8.6 shows 12k PARs on a feature set. Among tall downtown buildings in Los Angeles, the DP and gaffer maintained a consistent backlight all day long by lining up nine 12k pars on a rooftop 400 ft. from the set. Most manufacturers provide lenses with 12k and 18k pars, except the ARRIMAX, which uses a specially designed reflector to control flood and spot without lenses. Changing lenses on these lights is like working in a foundry—use gloves and large pliers or channel locks. Get thick, long leather gloves that cover your forearms if you are going to be doing it a lot, but if possible, change the lens when the light is off!

The ARRIMAX (Figure 8.7), currently the brightest of all HMIs, has some unique features worth noting. It has two interchangeable reflectors, a standard reflector (which provides a flood/spot range from 15° to 60°) and a spot reflector (8°-15°). Both can yield tremendous light output, with the spot reflector the light is capable of providing a working f-stop (52 FC) from 500 ft. away At 40 ft., it is as bright as the sun on a clear day in Los Angeles (8400 FC). With the flood reflector, you can get 60 FC at 150 ft. The ARRIMAX does not stress gels quite as badly as pars that use lenses, although in spot settings, it is still too hot for gels. In medium and flood positions a 4 × 4 gel can usually survive a reasonable amount of time when placed at least 19 in. from the light.

FIGURE 8.6

12k par fixtures line the roof of a downtown building giving an edge light to actors 400 ft. away and nine stories below. At that distance, the eight fixtures acted as a single source and did not cast multiple shadows.

(Courtesy Mike Bauman.)

FIGURE 8.7

As the sun sets, an ARRIMAX 18/12 is already burning, extending the daylight for a few more precious minutes.

(Courtesy Mike Bauman.)

Gelling large lights

Though the awesome power of large pars fills a niche no other light can, it also makes most of them essentially ungelable, especially when using medium or spot lenses. Gels work by absorbing selected wavelengths of light, and that energy converts into heat. The result, in this case, is that even 4-ft. × 4-ft. frames several feet from the light burn up almost immediately. Heat-shield (a clear, UV-absorbing gel used to save gels from heat) prolongs the fight for a minute or so before burning through. Even when gel doesn't burn through, the color will fade quickly with excessive heat. By the time you have completed one lighting setup, you may need to replace the gels. This makes color correction a problem. Very often, DPs and gaffers like to warm up HMIs using a ½ CTO correction. As the sun sinks in the afternoon and turns more and more orange, the correction on the lights needs to increase as well in order to match.

There are a few techniques and products that can help mitigate heat buildup in the gel:

- Use a frame of heat-shield spaced at least 18 in. from the gel.
- Perforate the gel with pinholes to reduce absorption and increase ventilation. This will help slow the fading of the gel color.
- Divide the work between two gel layers. For example, to accomplish a full CTO correction, use two frames of ½ CTO, or a frame of ¼ CTO followed by a frame of ¾ CTO (the first frame takes a bigger portion of the intensity).
- If you have the space, seam gels together onto 8-ft. × 8-ft. frames and place them as far from the light as possible.
- For HMIs up to 6k, you can have dichroic glass filters made for the color correction required (by Rosco and others).
- Rosco makes UV/IR glass filters that can be custom-made to fit any lamp. Using this filter in the lamp in combination with heat-shield spaced 18-in. from the gel gives the heat-shield a fighting chance. There is a small color shift from the filter.
- Rosco DichroFilm™ is a special dichroic 5-mil[2] flexible plastic that can be made to transmit any color. Rosco reports it has been successfully used in long-term applications with 20 k lights. At this writing, it is available in 10 standard colors, including full CTO, and custom colors can be made upon request. The material can be cut using scissors. The catch? A 25-in. square lists for $595.00.

Other precautions

At this writing, bulb failure is also a concern. Manufacturers recommend removing 6k, 12k, and 18k lamps before travel. These bulbs are heavy and supported only at one end. They can easily be cracked by vibration or a bump in the road or by being set down hard. Electricians need to be especially cautious.

In cold weather, the abrupt change of temperature when lamps are shut down can cause lenses to crack. You can avoid this by lengthening the time during which they cool down. Do this by adding scrims to the light a minute or two before shutting off the light. The hot scrims help slow the cooling of the lens when the light is shut off.

[2]A mil is one one thousandth of an inch. Mils are used to measure the thickness of materials.

HMI "open-face" lights

The ARRI X series and Desisti Goya lights are open-face lights featuring a very broad beam (almost 180°). They have only UV-protective glass in front of the bulb and reflector, no lens (Figure 8.8). The UV glass can be clear or frosted. Their beam is broad and unfocused. They can be oriented in any direction including pointing straight down as an overhead soft light (through heavy diffusion) or straight up for architectural lighting. They cast a hard shadow and would be a good choice if a hard silhouette were needed. They come in sizes of 200, 575, 1200 W, 2.5k, 4k, and 6k.

The Alpha series of HMIs, designed by a company called P56 and manufactured by K5600, are unique fixtures that defy categorization. The Alpha 2.5k/4k and Alpha 18k can be adapted as a Fresnel light, an open-eye fixture, or an overhead spacelight, and has an attachment to make a collimated shaft of light like a xenon or beam projector (Figure 8.9). The lights use a unique quartz composite reflector that looks like a flat white disk, rather than the typical aluminum reflector. This reflector is reasonably optically efficient, and can withstand extreme heat allowing these lights to be oriented in any direction including pointed directly downward. This would cook the reflector on most HMI Fresnels, but the reflector material and ventilated back panel of the Alpha are designed to do this. The 2.5k/4k Alpha has two interchangeable Pyrex Fresnel lenses, one with a spot focus range, the other with a flood focus range (11°–58° total range). The Space Beam accessory, available for both the 2.5k/4k and the 18k units, fits onto the front of the fixture, and using a thin lightweight plastic accessory lens, the beam is collimated to 4°. Both sizes of Alpha lights can also be implemented with no optics—open-eye with a 90° spread. Like an ARRI X or Goya, the open-eye configuration is great for creating very hard shadows and even light that spreads in all directions.

FIGURE 8.8

The ARRI X 40/25 Light is an open-face light, with clear or frosted UV protective glass.

(Courtesy ARRI Lighting.)

FIGURE 8.9

Alpha 2.4/4k is a compact, adaptable fixture that can be fitted with one of two Fresnel lenses, or used as an open-eye with a clear UV glass, or with a 4°-collimating lens (not shown). (Alpha series lights are designed by P56 LIGHTING, and manufactured by K5600, Inc. Photo courtesy P56 Lighting.)

Accessories

HMI Fresnels and pars have the same standard accessories as their tungsten counterparts: barn doors, scrim sets, gel frames. Chimera light banks are often used to turn direct light into soft light.

A remote yoke is a motorized unit used to pan, tilt, and focus (flood/spot) a light. They are very useful when getting a lighting technician to the light is impractical. An array of different devices are available on the market to accommodate any size light fixture; even the largest HMI light fixtures can be motorized and controlled remotely. Remote yokes are covered in more detail in Chapter 11.

Having an HMI come on or turn off on a cue presents a little more difficulty than it would with a tungsten unit. HMIs require a warm-up time of several minutes before the light can be used. Also, they cannot always be turned off and then turned on (while still hot) with total reliability. To work around this, a dowser unit (DMX512-controlled shutters) can be used to block the beam during the warm-up period, and to execute the ON and OFF cues. HMIs are commonly controlled this way in opera and theater lighting. The ON/OFF cues have to be arranged so that heat will not build up and warp the shutters, which will happen if they are left closed for too long. DMX512-controlled shutters and color scrollers are valuable accessories when this kind of control is required.

Small fixtures

Battery-powered HMIs, sun guns

A *sun gun* is a small (125, 200, 250, or 400 W) light that can be powered by a battery, usually in the form of a battery belt (Figure 8.10). The light has a handgrip as well as a mounting stud. Sun guns are handy where power is not available (e.g., "run and gun" mode out on the street, in a moving vehicle or a cave in the mountains of Mexico).

Although the 30-V NiCad belt batteries are supposed to last as long as an hour, rented batteries rarely keep the light going for more than 20-25 min. Lithium-ion batteries have greater amp-hour capacity and charge quickly. When battery-powered lights are to be relied on over the course of a whole scene or a whole day, it is necessary to have many batteries on hand. See Chapter 16 for more details about using batteries to power lights.

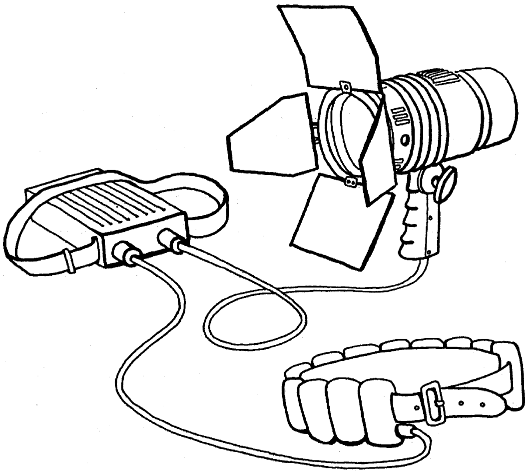


FIGURE 8.10

This HMI sun guns are available in low wattages of 125-400 W. They give daylight-color temperature (5600 K) operating from a 30-V battery belt.

ARRI also makes an AC/DC 575 W/1200 W ballast, which can be used to power 575 or 1200 W HMIs. This is a workable solution for free-driving shots (when the actor is actually driving and no tow vehicle is used). (More detail is in Chapter 16.)

Joker-bug

A number of manufacturers have adaptations for small daylight-balanced fixtures worthy of special note. K-5600 Lighting manufactures the Joker-Bug lights (200, 400, and 800 W), which are small fixtures designed with a unique range of applications: a highly directional PAR light, a soft light or lantern, a linear tube light, or as a lamp base that can be fitted to a Source Four ellipsoidal spotlight (Figure 8.11). In the Joker mode, the light is a small PAR fixture using an axially mounted single-ended MSR bulb in a parabolic, highly efficient reflector. The lights are very bright for their size. The spreader lenses allow wide control (the 400 ranges from a punchy 5° beam to a generous 55° spread). In the Bug mode, the “beamer” (the front housing containing the reflector) is removed, leaving only a bare omnidirectional bulb held in a UV-protective beaker. (Note that the Joker-Bug does not have a separate UV protection circuit; it operates with just three wires.) The Bug is used to illuminate a Chimera light bank or china lantern. The bulb can be oriented in any position. For lantern applications, the clear beaker is exchanged for a frosted one, which helps diffuse the source. Both the 200 and 400 Joker-Bug can run on battery packs using the Slimverter power supply, making the 400 one of the brightest sun guns available. They can also be run on any type of AC power.

The Softube is a 45-in. long by 6-in. wide white translucent tube that attaches to the front of the Joker-Bug light. It radiates soft light and inhabits a very small space, making it ideal for small spaces where daylight fill is needed (e.g., lighting a bus interior).

The Bug can be adapted to the Source Four ellipsoidal spot by removing the Source Four lamp housing and inserting the “bug-a-beam” adapter with the Bug 400. The result is a daylight-balanced

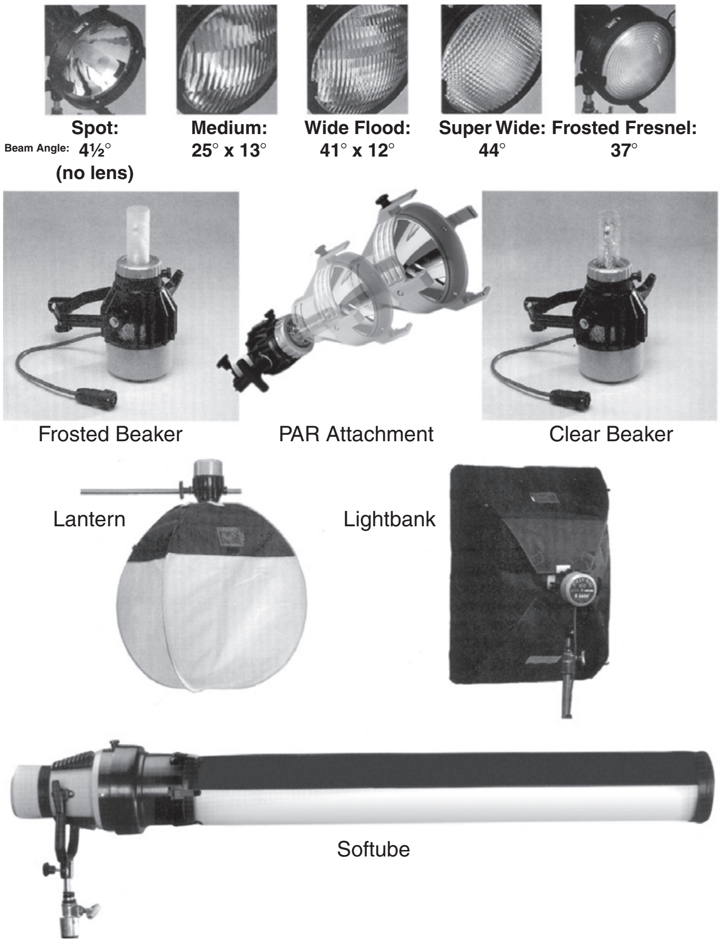


FIGURE 8.11

The Joker 800 in its many forms: par, bare beaker, lantern, chimera, Softube.

(Courtesy K5600, Los Angeles, CA.)

ellipsoidal spot with four times more brightness than normal. The short-arc MSR bulb is well suited to the task; the Source Four's beam is clean, sharp, and free of color fringing.

LTM has similarly designed light models: the Cinespace 125 W/200 W and Cinespace 575 W. These lights have a set of lenses that includes a frosted Fresnel as well as an assortment of spreader lenses. The front reflector housing twists off to adapt the light to a lantern or Chimera lightbank. Again, you have the option of a frosted or clear globe cover.

ARRI's variation on the theme is the Pocket PAR line of fixtures—125, 200, or 400 W miniature lights with their own unique set of accessories. These include a Light Pipe (same idea as the Joker-Bug Softube). The larger Pocket PARs have a Light House attachment much like the omnidirectional

Bug mode. They can also be fitted with an XXS Chimera lightbank to be used as an Obie, eyelight, or lantern. They can be powered from any type of AC service or from a 30-V battery pack with a DC power supply.

Dedo 400D

The Dedo 400D is another small daylight fixture with unique characteristics and accessories. Dedo lights are known for their sophisticated optical control. They offer superior light output per watt, a totally clean even beam that has a wide focusing range (from 5° at spot to 50° at full flood). In the flood position, they project a completely even field distribution. The ballast is dimmable, plus it has a boost position for additional light output. It has automatic input voltage selection (90-255 V AC). The projection attachment for the 400 series Dedo lights has the sharpest, cleanest beam I have seen on any light (rivaled perhaps by the Source Four fitted with a high-definition lens). The projection attachment accessories include framing shutters, iris, and gobo holder.

Tungsten-balanced arc-discharge lights

At this writing, a new type of arc-discharge light is starting to come to market. Ceramic lamps, developed by Philips, offer tungsten-balanced (3200 K) light, with CRI greater than 90, from an arc-discharge lamp. This has many benefits for portable application, the main one being lumen efficiency. A 250-W Ceramic puts out 22,000 lumens, a little more than a 750-W tungsten lamp. Ceramic lamps also have about four times greater lamp life (4000 h) than the tungsten equivalent and give out a quarter as much heat. The small arc size enables great optical efficiency for the light fixtures; 250 and 500 W sizes can burn in any position, and they will hot restrike. Unlike HMIs, ceramics can not be dimmed from the ballast.

ARRI makes a 7-in. Fresnel and an open-face ARRI X using the 250-W ceramic lamp. The ballasts are built right into the base of the fixture, and the fixtures plug right into the wall. The ARRI X Ceramic 250 has a nifty Chimera attachment that converts it into a softlight with output comparable to a 2k softlight, but using only 3 amps instead of 18. The design of ceramic lamps is made possible by improvements in the structural materials of the lamp, so far, up to 500 W. At this writing, larger sizes are a subject of research and development.

HMI OPERATION

In this section, we will discuss the normal operations of HMIs, including the safety circuits and ballast protective circuits that sometimes prevent them from working. A comprehensive discussion of HMI trouble shooting procedures is available on the *Set Lighting Technician's Handbook* Web site. This includes proper procedure for cable testing, ballast testing, and safety loop testing; common HMI problems, including flicker problems; and a fuller explanation of ballast electronics.

Setting up

The ballast circuit breakers should be off or the ballast unplugged while connecting or disconnecting head cables. The breakers should remain off while plugging in the power (Figure 8.12). This protects the front-end electronics from inrush current.

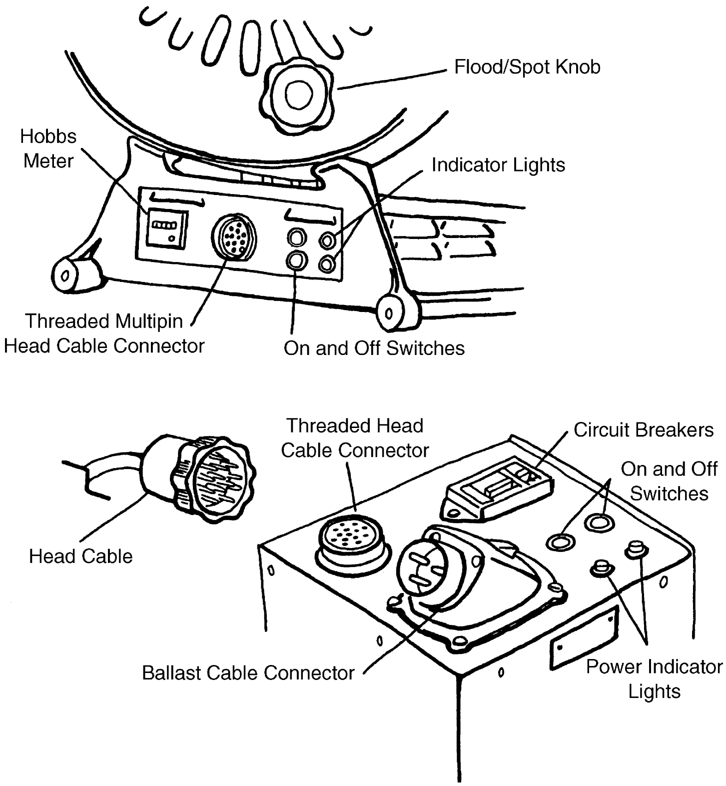


FIGURE 8.12

Anatomy of an HMI head and ballast. This illustration shows a magnetic ballast that uses an old-style socapex head-feeder connector. Modern ballasts in North America typically use VEAM connectors.

VEAM head cable connectors use a threaded collar that twist-locks onto the receptacle. Use the keyway to orient the plug into the socket. The VEAM[3] connectors for 575, 1200, and 2500 W are identical, except that the keyway is oriented differently. To tell the cables apart, some rental houses color-code the connectors or cables as follows:

Green	575
Yellow	1200
Red	2500
Blue	4k

[3]VEAM connectors are used in North America. In Europe, HMIs typically use Schaltbau connectors.

As with all connectors, the head cable connectors are a likely point of failure and must be treated nicely. Be sure to tie a tension relief so that the weight of the head cable does not pull on the connector, especially with larger lights that have heavy head cables.

Many electronic power supplies provide dual outputs so that they can be used with more than one wattage light: 575/1.2k, 1.2k/2.5k, 1.2k/1.8k, 2.5k/4k, 4k/6k, 6k/12k, 12k/18k, 12/18/24kW. There are even ballasts that can power four sizes—575/1200/2.5k/4k. Note that on many ballasts, both sockets are continually hot when the ballast is powered and on. Some manufacturers provide a flip-flop flap that covers the unused socket. You can also tape over the unused socket.

To assure reliability, HMI manufacturers recommend that no more than 150 feet of feeder cable be used between the head and ballast. The success of employing more than two 50-ft. head feeders at a time will depend mostly on the condition of the cables and the connectors. Connectors impose resistance. The more connectors there are, and the worse shape they are in, the less likely it is that the ballast will succeed in striking the light. For long runs, reliability is better using 100-ft. head cable in place of than two 50-ft. cables together. A single 200-ft. head feeder cable in good condition will work reliably (special-order item).

Avoid using cable that has been badly kinked; this creates resistance. Watch for connectors that show signs of being overheated or corroded. It is hard to detect the condition of crimp connections that may have loosened, and wires within the connector that are thin at the connection point. The best approach is thorough testing during prep.

Striking

Once the head cable is connected to the head and ballast, plug in the ballast and switch on the circuit breakers. Indicator lights on the ballast will light to show that you have power to the ballast. Some ballasts also indicate that a ground is present. This is labeled “PE” for Phased Earth on ARRI-style ballasts (see Figure 8.13).

With 12k and 18k Fresnel lights, place the bulb in the full spot position before pushing the ON switch. This backs the bulb away from the lens, so that the lens does not crack from thermal shock. Also, in the (rare) event that the globe explodes during warmup, the shattering of the lens is minimized. When 12k or 18k bulbs do explode, they often go within the first 5 or 10 minutes of ignition or reignition.

Before pushing the ON switch, call out “Striking” to warn people that the light is about to be ignited. HMIs have ON/OFF switches on both the head and the ballast, and most models can be turned ON and OFF from either place (except ARRI). When you press the ON switch, an electronic ballast may take 5-10 seconds to charge the capacitors, then the ballast briefly sends an ignition charge to the head, and this makes a sparking sound. The igniter circuit provides a brief ignition charge (about 0.5 seconds). The ignition voltage is very high: anywhere from 4500 V for a 575-W lamp to 20,000 V for an 18k lamp (and up to 70,000 V for hot restrike). The ignition charge creates a brief arc between the electrodes in the globe. Once the flow of electrons is initiated, the ballast brings the voltage down to the operating level and regulates the current.

Once sparked, the HMI begins to emit light. From a cold state, it takes 1-3 minutes for the substances in the globe to vaporize. At the same time, lamp voltage, lamp current, luminous flux, and color temperature all settle to their nominal values.

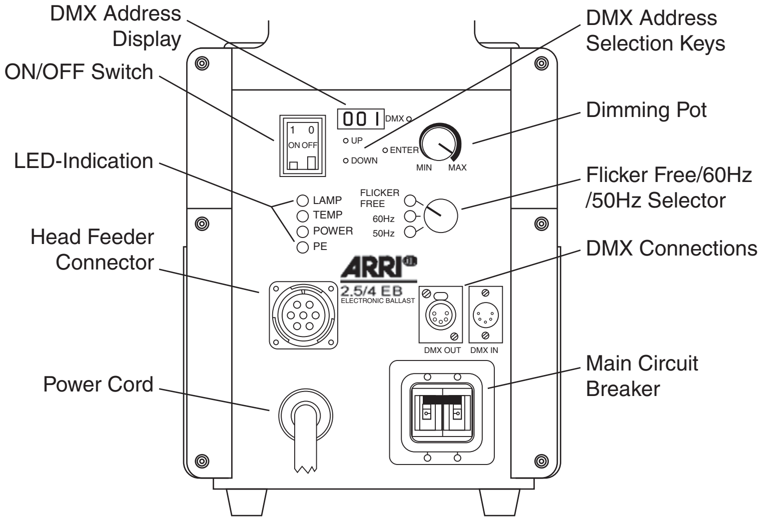


FIGURE 8.13

An ARRI 2.5/4 Electronic Ballast with DMX. A three-position knob selects 50, 60 Hz, or "flicker-free." The dimmer pot can dim the lamp to 50%.

(Courtesy ARRI Lighting.)

Reigniting a globe that is hot from recent use can present difficulty. Hot gasses inside the globe are under great pressure, creating very high resistance. To overcome this resistance and ionize the gas between the electrodes, a much higher ignition voltage is necessary. The electronics of most newer ballasts take this into account and have better hot restrike performance; often, however, an older magnetic ballast cannot produce sufficient voltage and you have to wait until the lamp has cooled (2 or 3 minutes) before you can restrike. This process can be hastened by opening the lens door to provide extra ventilation.

On/off switches, safety loop, and UV protection

There are six or seven active wires in an HMI head cable (depending on the light and manufacturer). Two of these wires—the big ones—provide power for the lamp. One is the ground wire connected to the light's metal housing and electrical parts. One provides current to the igniter circuit. This circuit is activated when you press the ON button to initiate the arc. The remaining wires are control circuits which serve two purposes: (1) they provide means for turning the light on and off from both the head and the ballast, and (2) provide a safety "Safe-On" loop circuit to the door of the lamp housing, to prevent the light from working if the lens door is open. On 120 V ballasts, the safety loop and switch circuits are typically 120 V. An actuator rod is depressed when the lens door is closed; this closes the safety loop switch, allowing the lamp to fire. If the light does not strike, or shuts off when pointed downward it is likely that the actuator rod is not closing the switch.

The "Safe On" loop circuit is necessary because direct light from an HMI lamp contains a dangerous amount of ultraviolet light. Once the light passes through a piece of glass, or bounces

off the inside of the fixture, the UV is diminished below a safe threshold. However the amount of UV in direct light is high enough to cause a burn, like a bad sunburn, very quickly. UV can cause retinal burns if a person looks toward a light that is not UV-protected even for just a few seconds, or if someone were to intentionally defeat the safety circuit. All HMIs therefore provide some sort of UV glass protection from the lamp and most include a safety circuit that prevents the light from operating without it.

Exposure to UV from a light is a product of three factors: time, distance, and intensity. The UV-protective glass is required to prevent a harmful level of UV from a particular light fixture over a period of 8 hours at a given distance. The distance is the same as the clearance distance recommended between the light and combustible materials. ARRI puts this information on a little metal plate attached to the fixture. A damaged or poorly made fixture that leaks direct UV radiation can, and has, caused skin burns, retinal burns, and even skin cancer. If prolonged proximity is unavoidable, as when operating a 12k or 18k in a condor, and you start to feel some burning on your skin, block radiation from the fixture and have the fixture replaced ASAP.

If some unusual circumstance requires a person (or any living thing) to be exposed for longer than 8 hours, UV exposure will still not exceed the safe level if the distance is proportionally greater than the minimum distance requirement. If a person has to be placed at a distance closer than the prescribed minimum, then the time must be reduced in inverse proportion to the increased intensity. In addition, it is entirely possible to use a higher-quality UV glass in situations where UV exposure could be a problem. DPs and producers may not be familiar with these issues. This is an area where the gaffer must provide the necessary guidance during preproduction.

Allowable camera speeds with HMIs

When using a magnetic ballast, or an electronic ballast operating in "silent" mode, the light intensity increases and decreases twice every AC cycle—120 times a second at 60 Hz. This fluctuation is not visible to the eye but can be captured on film as a rhythmic pulsation if the camera is not in precise synchronization with the lights. To avoid capturing light pulsation on the filmed image, you must:

1. Use a crystal-controlled camera, AND
2. Run the camera at one of a number of specific frame rates, AND
3. Use a line current maintained at exactly 60 Hz (or 50 Hz in many countries)

OR

4. Do none of the above, but use an electronic ballast set to "flicker-free."

The safe frame rates depend on the setting of the output switch on the ballast shown in Figure 8.13. When 60 Hz power is selected, it is easiest to remember that the safe frame rates are those that divide evenly into 120 (120, 60, 40, 30, 24, 20, 15, 12, 10, 8, 6, 5, 4, 3, 2, 1). When 50 Hz setting is selected, the easy-to-remember safe frame rates are those that divide evenly into 100 (100, 50, 33.33, 25, 20, 10, 5, 4, 2, 1). There are many additional HMI-safe frame rates, and frame rates that will work if the camera is adjusted to a particular shutter angle. These are listed in the tables in Appendix C. At any of these frame rates, the camera motor must be crystal-controlled. A wild or non-crystal-controlled camera can be used only when the HMI ballasts are running in "flicker-free" mode.

At one time, when the use of electronic ballasts was still relatively new, some manufacturers claimed square-wave ballasts would enable flicker-free filming *in silent mode* up to 34 fps. Everyone has backed down from this claim. All manufacturers now recommend the use of flicker-free frame rates in silent mode (60 and 50 Hz).

An electronic ballast set to "flicker-free" increases the frequency of the output voltage to 75 cycles per second. This broadens the safe windows of operation so that any frame rate or shutter angle can be used. Here too, HMI manufacturers once thought that these high frequencies would enable flicker-free frame rates up to 10,000 fps. It has since been shown that this is not always the case. Most manufacturers now claim flicker-free frame rates up to about 150 fps, and recommend practical tests before relying on the ballasts at higher speeds.

Unfortunately, the square wave causes the globe, igniter, and other parts of the head to make a high-pitched whistle. The head becomes a resonating chamber, amplifying the noise and projecting it toward the set and the microphones, which makes the sound department's job very difficult. To silence the ballasts when recording dialogue, electronic ballasts are fitted with a switch to change between flicker-free operation and silent operation (60 or 50 Hz). Typically, when the camera is running off-speed, you are not shooting dialog, so the ballasts are only switched to "flicker-free" when off-speed shots are taken, and are returned to "silent" mode afterward. In the silent mode, a special circuit electronically rounds off the sharp corners of the square wave, which eliminates the whine (Figure 8.14E). In "flicker-free" mode, the output frequency is increased and the ballast provides flicker-free light. You'll want to make sure that all ballasts are set to the same setting.

Strangely, the reproduction of flicker from off-speed camera situations is also affected by the optical qualities of the light fixture. Lights using double-ended globes and Fresnel lenses have been very successful using 75 Hz "flicker-free" ballasts at very high frame rates. However lights with highly efficient reflectors and direct light, such as SE pars and open-face HMIs, have been less successful. For years, 75 Hz provided an adequate window for flicker-free filming; however, recent HMI par light designs do show flicker at 75 Hz at certain frame rates.

If a par is used for high-speed photography, it should be used with a stipple or frosted stipple lens. Adding diffusion also helps. If par or open-face fixtures are being considered for high-speed photography, film tests should be performed in advance to assure a good outcome. Other variables also affect the reproduction of flicker including the amount of mixed lighting, and the distribution of lights across different power line phases. Lighting from a single source is the worst case.

Ballasts for very high frame rates

ARRI and Power Gems make ballasts for high-speed photography that use 300 Hz electronic ballasts. The 300-Hz ballasts are available in all sizes, from 125 W up to 18 kW. The higher cycle speed expands the flicker free window slightly when shooting on film at speeds up to 150 fps, and on low speed digital HS up to 500 fps. It has been reported that running 300 Hz into some types of igniters—particularly 18k—can blow the capacitor in the heads (with loud bang and smoke), so check with the head manufacturer for current information.

ARRI also makes 1000 Hz D-HS ballasts that are used in industrial applications for filming automobile crash tests at extremely high speed. They are available in sizes up to 4 kW. They work well at frame rates up to 1000 fps, and have been successfully used at rates up to 5000 fps. At 1000 Hz, the lamp noise is very pronounced—right in a frequency range where the human ear is most sensitive. One thousand hertz is also outside the recommended safe operating window for some lamps.

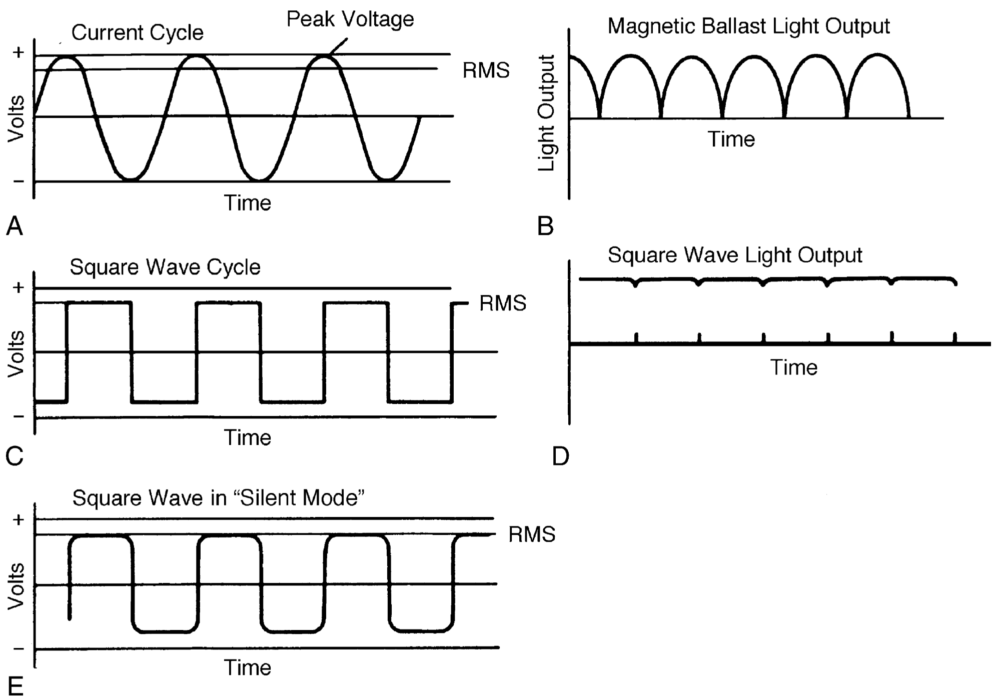


FIGURE 8.14

The normal sinusoidal 60 Hz voltage cycle of a magnetic ballast (A) creates a fluctuating light output (B), requiring that the camera frame rate be synchronized with the light fluctuations to obtain even exposure from frame to frame. The square-wave signal of an electronic ballast (C) creates virtually even light output (D), rendering the fixture flicker-free. The sharp corners of the normal square-wave signal create noise in the head. When operated in the silent mode, the ballast electronically rounds off the corners of the square wave (E). This diagram illustrates the concept a square wave as it relates to flicker. A real waveform on an oscilloscope does not look exactly like this.

Three-head, three-phase solution

One way to get around the HMI pulsation problem when operating at off-speeds or with a wild camera and magnetic ballasts is to use three standard HMI ballasts connected to three heads, each powered from a different leg of a three-phase source. Because the three phases peak a third of a cycle apart, when taken together, the three lights have an actual frequency of 360 peaks per second ($3 \times 120 = 360$). At this frequency, the camera does not detect the pulsation (Figure 8.15). The lights must be bounced or mounted close together and placed far enough from the subject not to create separate shadows. The light created is flicker-free at any frame rate.

Electronic (square-wave) ballasts

Square-wave ballasts offer other advantages over magnetic ones, not the least of which is that they are less heavy, and provoke less backache than ship-anchor magnetic ballasts. Electronic ballasts

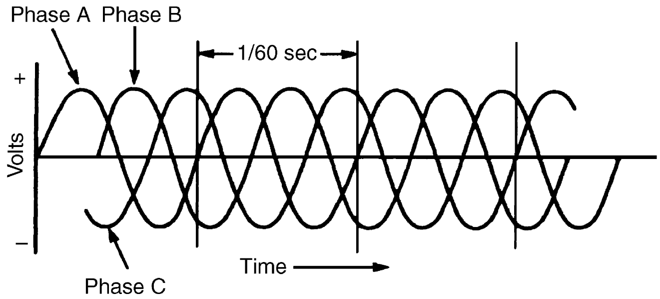


FIGURE 8.15

With three-phase power, the peak of each leg is a third of a cycle out of sync with the last, creating six peaks in each cycle. At 60 Hz, that amounts to 360 peaks per second, which is a high enough frequency to be flicker free at any frame rate.

completely process and regulate the input power, which provides additional advantages and features, including:

- Wide tolerance for voltage and hertz rate discrepancies. Typically ballasts will accept a line voltage from 90 to 125 V and 190 to 250 V. The line frequency can vary as much as 10% from one cycle to the next with no adverse effect on operation.
- "Dimming" capability: by controlling current, the ballast can dim the lamp 50%, or about one stop of light. At 50% power, a globe's color temperature is 75-200 K higher (bluer) than normal.
- Increased light output (5%).
- Increased globe life (as much as 20%).

The frequency of the output power is generated by the ballast itself. Most electronic ballasts have a 50-Hz/60-Hz output selection switch. This switch controls the timing of the output waveform from the ballast. With these ballasts, the output waveform has no reference to the line voltage hertz rate, so it will work with any supplied hertz rate. Normally, this switch would be set to 60 Hz in the United States (because we normally shoot at 24 fps); however, you can set this switch to 50 Hz to film at 25 fps, as was explained earlier. Of course, all the HMIs on the set have to be on the same setting.

In addition, modern *constant-power* electronic ballasts are able to regulate not just lamp current but lamp power, enabling the ballast to compensate for changing lamp voltage as a lamp ages. *Constant power* means that the lamp has a stable, optimal color temperature that remains uniform regardless of lamp age or line voltage. Constant-power designs are also less prone to overheating than constant-current ballasts (in situations where line voltage is low, current can become excessive).

DMX512-controlled ballasts

Ballast manufacturers offer DMX512-controllable versions of their ballasts. By linking multiple ballasts with a DMX512 control cable and setting an address on each ballast, you can turn units on and off and dim them to 50% from a central control console. This is a great convenience when dozens of lights are rigged up high and throughout the set. Manufacturers offer DMX512-controllable ballasts in all sizes 400 W and up, and DMX512 control as a retrofit to electronic and magnetic ballasts.

DMX512 ballasts typically use two channels—the first is the dimmer channel, and the second is on/off:

Channel	Fader value %	DMX value	Action of ballast
Channel 1	0–50%	0–126	Remains at 50%
	51%–100%	127–255	Dims level from 50% to 100%
Channel 2	0–50%	0–127	Lamp OFF
	51%–100%	128–255	Lamp ON

There is an "Enter" button on ARRI-style ballasts that must be pressed to accept a new DMX address (see Figure 8.13). A green LED on the ballast illuminates to indicate that the ballast is receiving a DMX512 signal. Note that the dimmer circuit within the ballast does not engage until the lamp reaches its nominal values after start-up. If the dimmer is set to 50% at startup, the light will come up to full brightness, and then engage the dimmer circuit and suddenly dim to 50%.

When controlling the ballast on a control console, the ballast must be switched on *from the console*. The dimmer pot on the ballast does not respond when the ballast is controlled remotely. You can disengage the DMX512 receiver in the ballast and regain local control by selecting address 000. HMI power supplies tend to be sensitive to cross-talk on the DMX512 cable. Keep the DMX cable runs away from the power cables and use an Opti-splitter if control problems occur. Running a clean DMX512 system is covered in detail in Chapter 11.

Ballast protective circuits and diagnostics

Modern electronic ballasts include protective circuits that shut down the ballast if it detects a problem. A shutdown can seem like a real nuisance, but until ballast manufacturers started incorporating protective circuits, electronic ballasts were constantly getting trashed. A short circuit in a head feeder would blow the output transistors. The electrician would then replace the ballast with a new one and blow that one too. According to one account, a bad head feeder (and one very determined electrician) once shorted out 13 ballasts in a row. In some cases, the ballast continues to work even though internal parts are damaged. The result is that other parts overheat and short out, and the repair bill and turnaround time keep going up.[4]

The *Set Lighting Technician's Handbook* Web site has lots of additional information about conducting intelligent diagnostics on heads, ballasts, and cables that can save a great deal of trial and

[4]The development of electronic ballasts with features such as constant power output, sophisticated diagnostic and protection circuits, and power factor correction is the result of years of struggle by ballast manufacturers to master reliability. Electronic parts in the older, simpler electronic ballasts were susceptible to trouble. For example, repeated hot stabs could burn out the inrush resistor that protects the front-end rectifier bridge diodes and capacitors during startup. The most common repairs to older electronic ballasts revolved around damage to input rectifiers, vented (blown) capacitors, open inrush resistors, or blown power module fuses—all caused by high inrush current. To protect the inrush resistor, be sure to turn off the main on/off switch or breaker after use and make sure it is off before plugging in the power cord. Another common repair on older ballasts is damage to the output transistors (IGBTs and FETs) caused by a short or arc path in the head or head cable. A shorted igniter circuit can burn out ballast after ballast.

error and headaches. It is a good idea to learn how to safely check the voltage from the ballast power circuit and igniter circuit, how to check continuity on the safety loop circuit, and how to test the head feeder cable. Performing these tests will locate the problem definitively in the majority of cases.

Indicator lights or self-diagnostic messages on an LCD display are helpful features provided on electronic ballasts (Figure 8.16). Ballasts that use a microcontroller can provide a greater range of diagnostics and control options. In the event of a shutdown, the microcontroller identifies the problem: an overheated power module, improper input voltage, a short in the output circuits, current on the ground wire, a misconnected cable—everything but a readout of the gaffer's blood pressure. If the ballast shuts off, don't be in such a rush that you forget to check the display before rebooting the ballast. Tables 8.1–8.3 list the various ballast indications and what they mean.

On Power Gems ballasts, a message will be displayed on the LCD alongside a flashing red light. Power Gems ballasts also keep an internal log of fault codes the ballasts experiences, as well as run times. To access the ballast's internal log, either hold down the blue button (marked "Full") for

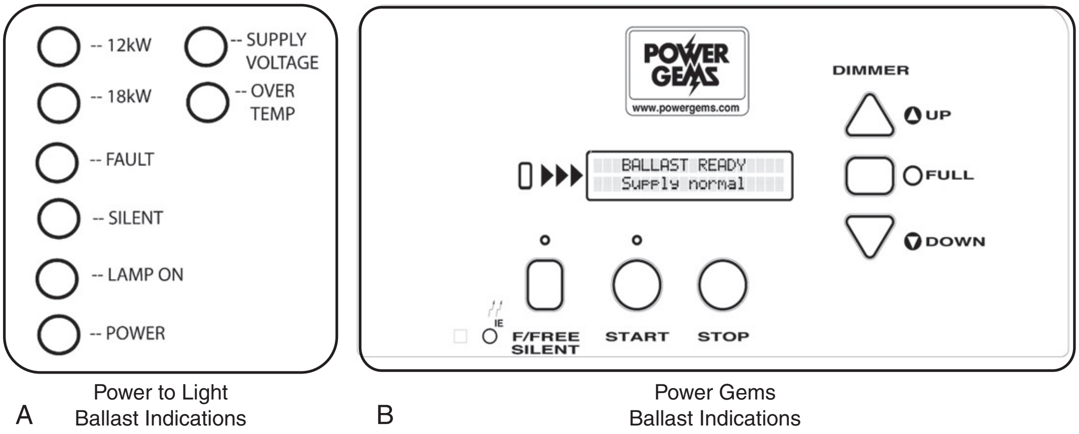


FIGURE 8.16

(A) Power To Light 18/12 kW Ballast Indicator Lights. (Courtesy John Parkinson, Power To Light, LTD.)
(B) Power Gems error display on their 18k ballast. (Courtesy Power Gems Corporation, Van Nuys, CA.)

Table 8.1 ARRI, B&S ballast indications

Indication	Meaning
Power light OFF	No supply power to the ballast, or breakers are off
PE light OFF	Ballast sees no ground connection to power supply
Temp light BLINKS	Ballast nearing overtemp (see next section for appropriate actions)
Temp light ON	Ballast over temp (shuts off)
Temp light ON	Ballast sees a short
DMX indicator	Lights to show presence of DMX512 signal

Table 8.2 Power to Light ballast indications (see Figure 8.16A)

Indication	Meaning
Lamp wattage lights (green) (12, 18 kW, etc.)	Shows lamp wattage currently in use. The 2.5-kW/4-kW and the 12-kW/18-kW models have auto-detect to change power. This means that it always starts at the lower power (e.g., 12 kW) and will change over to the higher power as an 18 kW bulb warms up. If the light is ON, the ballast has mains power, the breakers are on, and the ballast sees a continuous safety loop to the head.
Fault light (red)	This is a combined fault indicator, which will either light continuously or flash, depending on the fault. Faults can include earth current, short circuit, over-current or lamp failure. A continuous red light must be cleared by switching the main breaker OFF then ON.
Silent (blue)	Confirms ballast is in silent mode, not flicker-free mode.
Lamp on (yellow)	When ON, indicates that light has successfully struck. Blinking light indicates that the ignition sequence failed and the output has shut off.
Power (green)	Shows there is power to the ballast and the breakers are switched ON.
Supply voltage (red)	This indicator will light if the supply voltage is below or above limits. Voltage must remain between 170Vac and 260Vac. On some newer models, the light will flash when voltage is outside limits, but not yet at the trip point. This feature is installed on 4/6, 6/12, and 12 kW/18 kW models only.
Over temp (red)	A continuous red indication means an over temperature trip. The trip point is around 80° C on the inside face of the heat sink and is designed to protect the ballast from possible damage. Overtemp light installed on 4/6, 6/12, and 12 kW/18 kW models only.

Note*: The indicator lights used vary between models.*

5 seconds or use an infrared datakey. On ballasts with the blue button, the up/down buttons can be used to move through the memory. Table 8.3 associates a meaning to each [Fn] number listed in the log.

It is important to note that if the ballast indicates an error, it does not mean that the ballast is necessarily faulty. These ballast diagnostics will look for problems throughout the system. If you do need to check a suspect ballast, try it with a known good head cable and luminaire. *Do not* try a suspect luminaire on a working ballast, as this may damage the ballast.

Temperature

An electronic ballast will shut down if it gets above a certain temperature—112 °F for some, 122 °F for others, depending on how the electronics are configured. It is not hard to reach that temperature in the summer in the sun when the ballasts are sitting on a hot surface like concrete. The ballast will reset automatically, but only after it has cooled below the shutdown threshold. Some rules of thumb when heat is an issue:

- Do not place on a hot surface like cement, because the heat sinks will work in reverse. Place the ballast up on an apple box.
- Maintain airflow around the ballast.
- Do not stack the ballasts one on another; the lower ballast will overheat the upper one.

Table 8.3 Power Gems diagnostic display messages (see Figure 8.16B)

Error messages and behavior indications	Meaning
No Display	No power or breakers are OFF.
Fans running at high speed	Ballast nearing overtemp
CHECK LAMP/CABLE Break in safety loop	There is a break in the normally closed safety circuit. This could mean that the luminaire has been disconnected or that the lens door is open. The luminaire and the connecting cable should be checked. Some luminaries (ARRI) have an on/off switch; check whether it is in the ON position.
F1 NO LIVE/EARTH VOLTS Check Earth & Live	The ballast carries out a simple test to try to check that there is an earth connection to the ballast by checking for a voltage between phase and earth. If no voltage can be measured, the ballast assumes that the safety earth connection is missing and will not start. It is essential that the ballast is correctly earthed when in use, as very high voltages can be present if there is an igniter fault. Due to the simple nature of the test, it can cause problems in countries where phase and neutral are not discriminated. If this is causing problems, please contact Power Gems for details of how the test can be disabled.
F2 SUPPLY TOO HIGH Damage may result	The ballast has measured a supply voltage greater than 260 V and has shut down to protect itself. The message will stay on the display after the fault has cleared but the ballast can be restarted. Applying an excessive supply voltage to the ballast may lead to damage!
F3 SUPPLY TOO LOW Cannot Start or Run	The ballast has measured a supply voltage less than 190 V and has shut down to protect itself. The message will stay on the display after the fault has cleared but the ballast can be restarted. This supply cables may be too long or too thin; the voltage drop along the cable can leave insufficient voltage at the input to the ballast.
F5 OUTPUT TRIP Turn off to clear	The ballast has measured a current greater than 50/100/150 A (425/640/1260) in the output and has shut down to protect itself. This could be caused by an ignition problem or a fault inside the ballast. This is a serious error and the power must be switched off and on again to reset it. If it is persistently displayed even when the lamp is cold, it could indicate that something in the luminaire, head cable or possibly the ballast needs to be serviced. Contact Power Gems or a qualified service engineer for more information.
F6 EARTH TRIP Lamp earth current	An earth current has been detected in the output circuit and the ballast has shut down to protect itself. This could be caused by an ignition problem, a fault in the luminaire, or a wiring fault. This is a serious error and the power must be switched off and on again to reset it. If it is persistently displayed even when the lamp is cold, it could indicate that something in the luminaire or head cable needs to be serviced. Contact Power Gems or a qualified service engineer for more information.
F7 START FAILURE Lamp did not ignite	This means that after the ballast had finished running the igniter in the head it could not measure any current—the lamp did not strike. If it is persistently displayed, it could indicate a fault with the bulb, luminaire, igniter, head cable, or possibly the ballast. Get an electrician to check the bulb and that the igniter is running. Contact Power Gems or a qualified service engineer for more information.

Continued

Table 8.3 Power Gems diagnostic display messages (see Figure 8.16B)—cont'd

Error messages and behavior indications	Meaning
F9 OVER TEMPERATURE Allow to cool	The internal temperature of the ballast has gone above 85 °C. The ballast should be allowed to cool down with the fans running. To clear the message it may be necessary to press the stop button or to cycle the power off and on. Check that there are no obstructions to the airflow through the ballast, that you can hear the fans running and that the ambient temperature is less than 45 °C. It will help to keep the ballast cool if it is shaded from direct sunlight and run in an open area with space around it. In certain circumstances, standing the ballast off the ground may also help. Operation in confined spaces may lead to problems and should be avoided.
F11 OUTPUT HAS STOPPED Check bulb or cable	The lamp has gone out while running. This could be caused by a bad bulb or a wiring fault. Once the lamp has cooled down, try switching the ballast off and on again and restarting; a Start failure message would likely confirm that there is a fault.
F13 OUTPUT SHORT	The ballast has measured an output voltage less than 14 V and has shut down to protect itself. This could be caused by a short circuit in the head or head cable wiring or a fault inside the ballast. If it is persistently displayed, check for any wiring problems and contact Power Gems or a qualified service engineer for more information.
F13 INTERNAL FAULT DC charge failure	The ballast is unable to measure any voltage on its main capacitors (EB425CDP range only) and will not start or run to prevent damage. Switching the power off and on again may help to clear the fault, but if it persists, the ballast should be sent to Power Gems or a qualified service engineer for repair.
TURN OFF, then turn ON to clear.	Ballast must be switched off and on again to clear a previous fault.
INTERNAL FAULT Input data failure	The ballast has detected a break in communications between the two microcontrollers inside and is not able to carry on running. If this error message is persistently displayed, the ballast will need to be sent to Power Gems or a qualified service engineer for repair.
POWER CONTROL PCBs WRONGLY INSERTED	The ballast has detected a break in the internal safety loop circuit that runs through the four main PCBs (EB425CDP range only). If this error message is persistently displayed, the ballast will need to be sent to Power Gems or a qualified service engineer for repair.

The F-number refers to the code stored in the memory. (Courtesy Power Gems.)

- Do not place the ballasts where they are heated by hot lights. Do not point hot lights at the ballasts.
- Place the ballasts in shade or create shade for them (but don't inhibit the free flow of air in doing so).
- If the ballasts are in a place where there is little circulation, use a fan or AC duct to force air across the ballasts.

Power To Light and Power Gems ballasts use variable-speed fans controlled by a combination of power setting and temperature. The fans automatically speed up when the internal temperature sensor detects air temperature above a certain level (e.g., 86 °F for Power To Light ballasts). The fans may shut off when the temperature is less then 50 °F.

A certain amount of care and forethought are required in cold temperatures too. The main problem arises when a cold ballast is brought indoors, condensation forms all over the inside of the ballast, then the ballast is taken back out in freezing temperatures and the condensed moisture freezes. This scenario can literally freeze and lock up the relays.

Power factor correction

Electronic ballasts that do not have power factor correction (PFC) circuits have some undesirable electrical characteristics. These include 70% electrical efficiency (reduction in generator capacity, and higher fuel consumption), high spike currents that adversely affect the power supply or generator, more heat and ware to the ballast, and excessive current returning on the neutral wire. A *PFC circuit* realigns the waveform, returning it to as much as 98% efficiency, and inducing a smoother waveform. ARRI uses the phrase *active line filter* (ALF) to denote PFC plus line filtering.

European electrical codes require the use of PFC when devices like electronic ballasts are used with mains power, but PFC is not required in the United States, though this is likely to change eventually. All manufacturers now include PFC on 12k/18k ballasts. For these high-current units, PFC becomes not just desirable but necessary to protect the electronics from extremely high currents and overheating. For ballasts 6k and lower, manufacturers offer PFC as an option. However, because of the added cost, weight, and complexity, rental houses may or may not stock PFC ballasts, at least not exclusively. The gaffer or best boy must specify that PFC ballasts are required when ordering the equipment.

When large numbers of ballasts are to be used, there is potential for some serious power headaches and PFC is advisable. PFC can also be handy when you are plugging small lights into the wall at a location. A non-PFC 1200 W ballast draws almost 20 amps, so if the circuit is carrying any other load, the breaker could be overloaded. A 1200-W PFC ballast draws just under 12 amps, leaving enough leeway for another light to be added to the same circuit. Also, if you are running HMIs on a small portable generator (like a Honda 5500 or 6500 W), PFC is going to help in a number of ways: it is a much more efficient use of limited power resources, it gets rid of spike currents that can wreak havoc on a little alternator, and PFC ballasts manage fluctuations in input voltage better. See Chapter 16 for more about using HMIs with small generators.

We'll talk more about power factor in Chapter 14, but here is an introduction to the concept. With a normal incandescent load, when voltage is applied, current flows in lock step with the voltage. Think of the sine wave of alternating current: voltage and current increase and decrease together at 60 Hz. An incandescent fixture provides only resistance—it is called a *purely resistive load*. However, an electronic ballast uses large capacitors that draw current in such a way that current leads the voltage. This is called a *capacitive load*. In the AC cycle, the current rises and falls ahead of the voltage, typically by about 45 degrees (a quarter cycle) in a non-power-factor-corrected ballast. With the voltage and current out of phase, the voltage and current never peak at the same moment; the efficiency of delivery of power is reduced by a factor of 0.7, in this case. This is called the *power factor*. It is equal to the cosine of the phase angle between current and voltage ($\text{pf} = \text{Cos } 45^\circ = 0.7$). For a purely resistive load, voltage and current are in phase and the power factor is 1.0 ($\text{pf} = \text{Cos } 0^\circ = 1.0$), also known as *unity power factor*. When voltage and current are 45° out of phase, the ballast can use only 70% of the power it draws, or, to put it another way, it has to draw 30% more power

than it uses. The rest is current cycling back and forth between the power source and the ballast, creating amperage in the cables, without doing any actual work. This has several consequences, none of them good. It means the generator has to work 30% harder, use 30% more fuel, and have 30% less capacity available for lighting. It also means the ballasts works harder, generates more heat, and ages sooner.

Because the capacitors are charging only at the peak of the sine wave, spike currents can reach 2½ times those of the equivalent sinusoidal waveform. This creates extremely high loads on the service transformer or generator. Generator suppliers complain that this can interfere with the generator's voltage regulator and even burn out the alternator. To contend with spike currents, some suppliers recommend the generator be oversized to at least twice the size of the load, when the load has a low power factor. And they warn that spikes may also affect other units running on the same service.

A low power factor also means a high *return current* on the neutral wire in the distribution cable, and the neutral wire needs to be doubled or even tripled to handle the excess current. With a power factor of 1.0, when the phase wires (red, blue, and black) are evenly loaded, the current cancels out between the phases, and the neutral wire carries only the difference between phases. With a power factor of less than 1.0, the load on each of the phase wires does not cancel out even when they are evenly loaded. With a power factor of 0.7, for example, 30% of the current does not cancel between phase wires; instead, it adds up on the neutral. So you would have to carry 90% of the load on the neutral, even though all phase wires are evenly loaded (assuming here that you have three-phase service).

PFC circuits successfully increase the power factor to as much as 0.98. The ballast uses power more efficiently with minimized return current and line noise, and also reduces heat, thereby increasing reliability.

Load calculations

When calculating the power requirements of HMI lights, the actual power a ballast consumes is greater than the wattage of the lamp itself. Calculations must make allowance for power factor and the efficiency of the power supply. Table 8.4 gives the power requirements of ballast models available at the time of publication. Apparent power, given in volt-amperes (VA), is the amount of power the ballast actually requires to run. Current can be calculated by dividing apparent power by the actual mains voltage while under load. True power, given in watts, is the amount of power the light actually uses.

Apparent power is related to true power as follows:

$$\text{Apparent power} = \frac{\text{Wattage of the lamp}}{\text{Power factor} \times \text{Efficiency}}$$

Efficiency of electronic ballasts is usually between 0.88 and 0.94. Power factor varies with the ballast and may be as low as 0.60.

Installing an HMI lamp

It is a wise precaution to remove the lamp from large HMI fixtures before transporting them. This is especially true for 12k and 18k lamps, and for the larger axially mounted single-ended lamps as well. It is up to the best boy to decide how far he or she wishes to take this, but all the larger lamps sizes

Table 8.4 Apparent power and amperage of PFC and non-PFC electronic ballasts

	B&S, ARRI		**Power to Light**		**Power Gems**	
Wattage	Non PFC (0.58-0.72)	PFC (0.98)	Non PFC (0.65-0.75)	PFC (0.97-0.98)	Non PFC (0.65-0.67)	PFC (0.97-unity)
125 W	—	150 VA (1.25 A @ 120 V)	—	—	—	—
200 W	—	240 VA (2 A @ 120 V)	—	—	336 VA (2.8 A @ 120 V)	—
400 W	—	465 VA (3.9 A @ 120 V)	966 VA (7.2 A @ 115 V) (4.2 A @ 230 V)	—	642 VA (5.8 A @ 110 V)	—
575 W	1100 VA (9 A @ 120 V) (5.3 A @ 208 V) (4.6 A @ 240 V)	670 VA (5.6 A @ 120 V) (3.2 A @ 208 V) (2.8 A @ 240 V)	966 VA (7.2 A @ 115 V) (4.2 A @ 230 V)	—	902 VA (8.2 A @ 110 V)	—
1200 W	2290 VA (19 A @ 120 V) (11 A @ 208 V) (9.5 A @ 240 V)	1390 VA (11.6 A @ 120 V) (6.7 A @ 208 V) (5.8 A @ 240 V)	2024 VA (17.6 A @ 115 V) (8.8 A @ 230 V)	—	1850 VA (16.8 A @ 110 V)	—
2.5 kW	3900 VA (33 A @ 120 V) (19 A @ 208 V) (16 A @ 240 V)	2900 VA (24 A @ 120 V) (14 A @ 208 V) (12 A @ 240 V)	3680 (16 A @ 230 V)	—	4030 VA (36.6 A @ 110 V)	—
4 kW	6200 VA (52 A @ 120 V) (30 A @ 208 V) (26 A @ 240 V)	4650 VA (39 A @ 120 V) (22 A @ 208 V) (19 A @ 240 V)	—	4310 VA (39.0 A @ 110 V) (18.7 A @ 230 V)	—	4200 VA (38.2 A @ 110 V) (20.2 A @ 208 V) (17.5 A @ 240 V)
6 kW	9600 VA (46 A @ 208 V) (40 A @ 240 V)	6900 VA (33 A @ 208 V) (28 A @ 240 V)	—	6394 VA (30.7 A @ 208 V) (27.8 A @ 230 V) (26.6 A @ 240 V)	—	6600 VA (31.7 A @ 208 V) (27.5 A @ 240 V)

12 kW	18,000 VA (87 A @ 208 V) (75 A @ 240 V)	13,200 VA (63 A @ 208 V) (55 A @ 240 V)	—	12,995 VA (62.5 A @ 208 V) (56.5 A @ 230 V) (54.1 A @ 240 V)	—	13,100 VA (63 A @ 208 V) (54.6 A @ 240 V)
18 kW	—	19,400 VA (93 A @ 208 V) (81 A @ 240 V)	—	19,274 VA (92.7 A @ 208 V) (83.8 A @ 230 V) (80.3 A @ 240 V)	—	19,400 VA (93.3 A @ 208 V) (80.8 A @ 240 V)
24 kW	—	Contact manufacturer	—	Contact manufacturer	—	25,376 VA (122 A @ 208 V)

Not all manufacturers sell a US version (120 V) of all the products they make.
Performance varies slightly between different models of the same wattage within each manufacturer's line. To keep this table simple and provide a guide for safe power planning, the model with the higher current is listed in this table. The differences are small. You can check the specification plate on the ballast you are using to get actual rated apparent power or amperage.
These figures are manufacturers' specifications for new ballasts at the time of this research, 2009. Manufacturers continually improve their products over time. Specifications for models older or newer than 2009 will vary.
Manufacturers vary in the way they present data. Some figures shown here are calculated by the author from the data given.

are long enough and heavy enough that strong jolts during transport could crack axially mounted lamps at the ceramic base. Keep in mind that these lamps are hand-made, not machine-manufactured. At this writing, a single-ended 18k lamp goes for about $1837. Single-ended lamps in a Fresnel fixture are not subject to as much strain, because they are mounted vertically in the light fixture.

Before relamping a light, be sure that the breakers are off, the fixture is unplugged, and the lamp is completely cooled. HMI bulbs build up internal pressure when in use. It is dangerous to handle them when hot; if broken, they will explode, sending shards of hot quartz in all directions.

The golden rule when relamping any fixture is never to touch the quartz envelope with your fingers and never to allow moisture or grease to come into contact with the bulb. Even a light smudge of finger grease causes a hot spot on the quartz envelope, which weakens the quartz and causes the envelope to bubble. When the globe loses its shape, the globe's photometric and structural properties are compromised and the globe could fail. HMI globes are too expensive to handle carelessly. When an HMI globe explodes, it can shatter the lens and destroy the lamp holder and reflector, bringing the total loss to a staggering sum. Always handle globes with a clean and dry rag, with clean cotton gloves (editor's gloves), or with the padding in which the globe is packed. Follow the globe manufacturer's recommendations for cleaning the globe once it is mounted in the fixture. They often recommend wiping the globe with a presaturated alcohol wipe or isopropyl alcohol and a clean lint-free tissue.

The vast majority of HMI lights now use single-ended globes. With SE PAR fixtures, it is sometimes impossible to install or remove the globe without handling it by the glass. Care must be taken to avoid breaking the glass where it attaches to its ceramic base. Hold the glass with clean cotton gloves or a clean rag, and wiggle the globe gently along, not across, the axis of the pins; any stress across the axis can very easily snap the quartz.

Most fixtures have a lamp-lock knob on one side of the fixture (shown in Figure 8.5); turning this knob counterclockwise 90° releases the lamp from the base. The tightness of the base can be adjusted in the shop. Proper adjustment allows for some expansion of the lamp pins when hot. A base that is too tight puts stress on the lamp base and can cause lamps to crack with expansion.

A single-ended lamp base not *fully* inserted into the socket is a common cause of costly meltdowns. As we have said, 12k/18k light can have extremely high ignition voltage. If the pins are not fully inserted, at high voltage electricity will arc between the pins of the lamp with devastating consequences. On the ARRIMAX, ARRI designed a ceramic feeler into the lamp socket that is connected to an indicator located beside the lamp lock handle (on the ARRIMAX, this is accessed through a little door on the left side of the housing). When the lamp is fully seated, the indicator lines up with an arrow to give the operator positive confirmation that the lamp is fully seated. Regardless of which light you are lamping, be sure that the pins are fully inserted into the socket before locking the lamp.

The 18k single-ended lamps are manufactured with two base sizes: G38 or G51; 12k single-ended lamps use the G38 base. To accommodate this, some manufacturers use dual-size sockets that can take either size of lamp.

Some lamp manufacturers specify that double-ended globes should be installed with the molybdenum ribbon horizontal so that it does not block light returning from the reflector (Figure 8.17). Some specify the orientation of the nipple of the quartz envelope. Take a look at the manufacturer's recommendations for installation.

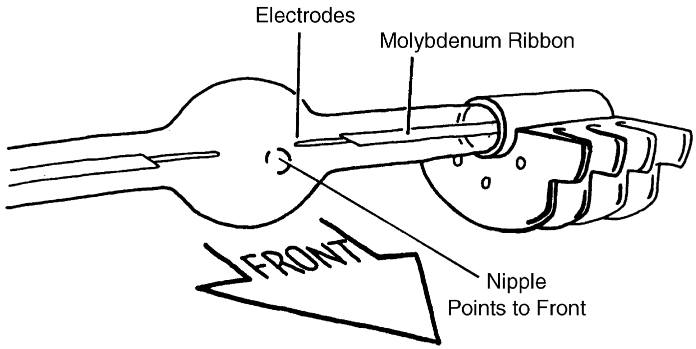


FIGURE 8.17

Installation of a double-ended HMI globe. Note that the ribbon is horizontal and the nipple is oriented outward (it may also be oriented upward). Connections are tight. HMI globes should be cleaned with an alcohol-impregnated cloth after installation, in accordance with the lamp manufacturer's recommendations. Note that some manufacturers make different installation recommendations; check the documentation that comes with the lamp.

For large single-ended lamps, some manufacturers specify that the rod should be oriented above the envelope; others say that it should be below the envelope. Osram says it doesn't matter which way it is installed. You just have to read the instructions that come with the lamp.

Color temperature

As explained earlier, the color output of lamps in the HMI family is not a continuous spectrum. The way it works is this: a lamp consists of two tungsten-coated electrodes surrounded by mercury vapor and other metal halides held in an envelope. The flow of electrons switches electrons in the gas from one highly excited state to another, releasing energy in the form of visible and UV light. Though the mercury is responsible for most of the light output, an optimal mix of halides of rare earth metals in the mercury adds many additional wavelengths of light. The result is a *multiline spectrum*, meaning that the color is made up of narrow peaks of various wavelengths rather than a continuous spectrum; this closely resembles the makeup of daylight and renders colors faithfully on film.

It is an inconvenient truth that commonly used color temperature meters like the Minolta Color Meter IIIF, that provide "photographic color temperature," are not capable of reading metal halide discharge sources with consistent accurately. Both Minolta and Philips have released explanations of this, and they do not themselves recommend this practice. The explanation is given in Chapter 6, where we talk in detail about color meters. Suffice it to say that meters like the Minolta IIIF are meant to read continuous sources such as a tungsten lamp, and they have been found to be inaccurate by as much as 1000 K when measuring discontinuous sources such as metal halide discharge lamps and LEDs. It has also been suggested that greater accuracy can be achieved by taking the color reading off a white card, rather than the source directly.

Factors that affect the color output of HMIs are the type of globe (5600 or 6000 K), age of the globe, lamp cooling, and the voltage regulation of the ballast. When an HMI globe is brand new,

it often shows a very high color temperature (10,000-20,000 K). This is sometimes accompanied by some arc instability, causing flicker. You may want to "burn in" the globe, if it is brand new, before filming starts, or color-correct the light. During the first couple hours of use, the color temperature comes down quite quickly to the nominal value (5600 or 6000 K) and the arc stabilizes.

Constant-power electronic ballasts regulate lamp power in such a way that color temperature remains constant as the electrodes age. When a fixture is dimmed on an electronic ballast, the color temperature rises slightly (goes bluer) as the voltage is reduced to 50%. With magnetic ballasts, the color temperature decreases over the life of the globe at the rate of 0.5-1 K/hours depending on conditions. The color temperature decreases because as the gap between electrodes increases, more voltage is required to maintain the arc, and as the voltage increases, the color temperature decreases.

Because the characteristics of the lamp and ballast both affect the color output, it was once common practice when using magnetic ballasts to match heads to ballasts and number and label the head, the ballast and the lamp's storage box with the color temperature and the amount of green that the light emits. For example, a head and ballast would be labeled:

$$\#1, 5500\,\mathrm{K}, +2, 5/13/10$$

This indicates that ballast 1, which is matched to head 1, 5500 K color temperature, has a +2 CC of green on the date shown. With modern constant-power ballasts, matching ballast and lamp is no longer necessary. Lighting technicians typically just check the color temperature of the lamp during the load in, to see where the color temperature has settled for that particular lamp, and mark this on the head.

For safety reasons, manufacturers recommend that globes not be used for more than 125% of their rated service life. As the bulb ages, changes in the quartz glass envelope make the globe increasingly fragile.

Metal halide arc lamps

Different globe manufacturers use their own registered trade names for lamps in the HMI family:

HMI (Hg [mercury] medium-arc iodide; Osram)
HMI/SE (single-ended; Osram)
Tru-Arc (single-ended and double-ended; Wolfram)
MSR (medium-source rare earth, single-ended; Philips)
MSI (double-ended; Philips)
Ceramic (tungsten-balanced; Philips)
CSR (General Electric)
CID (compact indium discharge; Thorne, UK)
CSI (compact source iodine; Thorne, UK)[5]
DAYMAX (ILC)
BRITE ARC (Sylvania)
UMI (double-ended; Ushio)
USR (single-ended; Ushio)

[5]CID and CSI are used in stadium lighting. CID is also used in small sun-gun fixtures and has the same color characteristics as HMI globes.

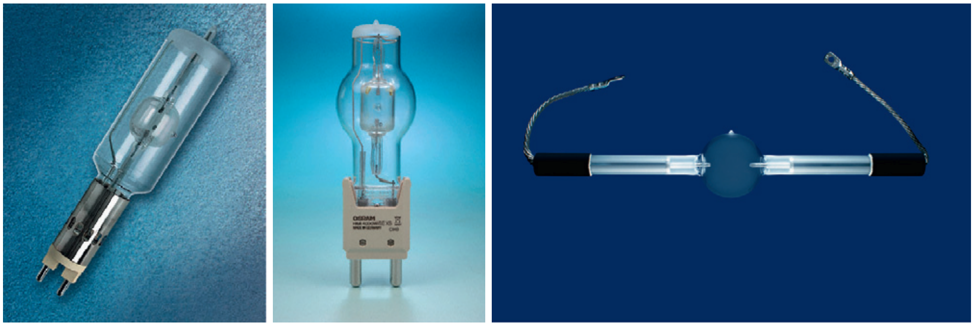


FIGURE 8.18

From left to right: a 12kW single-ended lamp, a 4kW single-ended lamp, and a 24kW double-ended lamp.

(Courtesy Osram Corp.)

The two kinds of HMI globes, single-ended and double-ended, are shown in Figure 8.18. The design of single-ended (SE) globes allows for greatly improved efficiency when mounted axially and used with a bright reflector, as in SE PAR fixtures. They are also used mounted vertically in some models of Fresnel fixtures. Single-ended globes of 575 W and larger can generally be burned in any orientation. The design and short overall length of SE globes make it easy for them to restrike while hot.

Burn angle

Lamp manufacturers publish limitations on the angle of tilt at which a given light can be used based on the need for proper cooling of the lamp. Most Fresnel and par fixtures that use single-ended globes have a good range of tilt. Lights under 4k can generally be pointed straight up or down. Fixtures 4k and over are generally limited to 75° up or down from horizontal. Double-ended HMI lamps generally are assigned a more restrictive range of up/down tilt and also have restrictions on how much they can be operated tilted sideways—usually plus or minus 15 degrees left and right.

Mercury

HMI globes contain very small amounts of mercury, which is poisonous. If a globe breaks, take sensible precautions to prevent ingestion of toxic chemicals. Keep chemicals off your hands. Wash your hands. Dispose of broken and burnt-out bulbs in an appropriate place. Burnt-out globes must be returned to the rental house for inventory.

CHAPTER

9 Fluorescent lights

At one time, cinematographers regarded fluorescent lighting as a minefield of photographic headaches, and virtually incompatible with motion-picture photography. Fluorescents were associated with ghoulish green skin tones, poor color rendering, anemic light output, noisy humming ballasts, and shutter speed restrictions (the same as HMIs with magnetic ballasts).

In the 1980s, confronted with the inevitable need to shoot under fluorescents, many gaffers put together their own fluorescent systems. They wired newly available solid-state ballasts to kluged lamp harnesses, and sought out new commercially available tube designs that provided a better color spectrum. Color correction gels were developed for a range of fluorescent lamps. The results rendered fluorescent environments filmable, but color and light output were still far from ideal.

It took the innovations of a determined gaffer and his best boy to overcome these obstacles. Freider Hochheim and Gary Swink designed fixtures, ballasts, and lamps tailored to the needs of film production. Their company, Kino Flo, Inc., continues to make groundbreaking advances in the photographic applications of fluorescent technology. There are now many manufacturers making fluorescent fixtures for motion picture, television, video, webcasting, and still photography, typically featuring stand-mountable fluorescent fixtures with high-frequency, flicker-free ballasts, which operate with commercially available lamps. Kino Flo and Lumapanel have developed their own lamps custom-made lamps.

With this film-friendly fluorescent technology, cinematographers discovered the many invaluable qualities of fluorescent lighting: lightweight fixtures that put out soft, controllable light that wraps around an actor's face and creates a pleasing eye light, and which they can use in daylight and tungsten lighting situations. The lamps can easily be built into sets when a fluorescent environment is called for, but fluorescent movie lights are most commonly used purely as versatile, a low-profile, cool-running soft light (Figure 9.1). In addition, blue and green custom designed tubes with narrowly limited color frequency and very high lumen output are invaluable for lighting blue or green screens for matte photography (Figure 9.2). Fluorescents are among the most power efficient lights made, and more lumens per watt also means less heat emitted, less power is wasted (Figure 9.3). A cooler work environment means less sweat, and less time fixing the actor's makeup and hair. As these products have evolved they have become even more sophisticated, incorporating dimming, DMX512 control, more efficient lamp and reflector designs, and a host of other features discussed in this chapter.

In this book, we focus primarily on products from two companies: Kino Flo and T8 Lumapanel. Lights made by others have certain commonalities with those described here. Other manufacturers include LiteGear's (X-Flo), Mole-Richardson (Briax), Flo Co., ARRI (Studio Cool), Balcar,

Set Lighting Technician's Handbook, 4e. DOI: 10.1016/B978-0-240-81075-1.00009-X

FIGURE 9.1

An array of 4- and 2-ft Kino Flo fixtures hung on a pipe in a practical location.

(Courtesy Kino Flo, Inc.)

FIGURE 9.2

Kino Flo Image 80s with blue tubes light a giant blue screen, and are easily controlled from the lighting console.

(Courtesy Kino Flo, Inc.)

FIGURE 9.3

More than 120 Image 80 fluorescent fixtures backlight a translight backdrop. The lights were chosen to avoid the heat and massive power requirements that come with lighting a backing this size with incandescent lights.

(Courtesy Mike Bauman.)

Videssence, Brightline, Desisti, Bron Kobld (Lumax), and others. Detailed, up-to-date information can be found on the manufacturer's Web sites (see Appendix F).

One feature unique to Lite Gear's X-Flo (Figure 9.4) and Mole-Richardson's Biax fixtures is the ability to be dimmed using phase control dimming (power line dimming). A fixture like the X-Flo can be plugged into a dimmer line, a variac dimmer, or even a household dimmer. This makes them

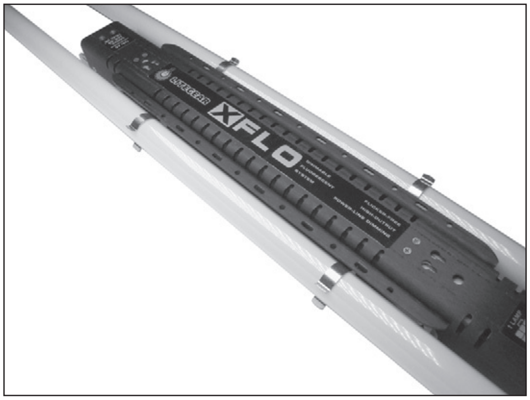


FIGURE 9.4

Unlike many fluorescent lights, the X-Flo can be dimmed by the power line—plugged into a dimmer pack or household triac dimmer. The X-Flo uses GE Cinema Series 55 W high output T-8, or BAIX lamps. The X-Flo design allows the lamps to be clipped directly to the flicker-free ballast in one compact self-contained unit. It can be mounted using zip ties, a stand, a clamp, or screws.

(Courtesy Al DeMayo, LiteGear, Inc.)

extremely handy for lighting on-camera set elements such as milk-Plexiglas (or any translucent surface), in soffits, under cabinets, behind bottles at a bar, and so on, where easy exposure adjustment is critical.

KINO FLO LAMPS AND BALLASTS

Almost all florescent light manufacturers use off-the-shelf lamps and electronics. Kino Flo has been designing lights since long before workable off-the-shelf options were available, and as a result, from the start they have designed their own tubes and ballasts. By customizing the electronics and chemical makeup of the lamps, the system is optimized for brightness, true color rendition (CRI 95), reliability even under harsh conditions, flicker-free operation, quietness, and similar criteria required for production work. The power supply is designed to drive the lamps at a high output, and the lamps are designed to create good color output when driven in that way. They are maximized and matched to one another.

Kino Flo's original fixtures were designed for standard size, T12, fluorescent tubes in 2- and 4-ft lengths. Kino Flo has since developed a wide variety of fluorescent tubes and lighting fixtures from tiny 4-in. tubes to enormous walls of fluorescent light banks. Most recent developments include high-efficiency light fixtures using Kino Flo's own version of T7 compact fluorescent lamp (CFL). The efficiency of CFL lamps in Kino's fixtures more than doubles the light output of T12 fixtures and puts these powerful, low-wattage fluorescent lights in a class of their own.

Kino Flo's broad-spectrum fluorescent lamps are engineered to correspond with the spectral sensitivity curves of color film emulsions. Lamps for all Kino Flo fixtures are available in either daylight or tungsten color temperature. T12 are available as the following models: KF55 (5500 K), KF32 (3200 K), and KF29 (2900 K). Kino Flo's CFL and QFL lamps are available in 5500 K and 2900 K.

Kino Flo tubes mix wide- and narrow-band phosphor crystals with rare earth elements. The phosphor blend displays a complete spectrum of light (Color Rendering Index of 95) and no green spike when operated with Kino Flo high-output ballasts. (Appendix B lists all Kino Flo tubes in Table B.2, and Figure B.1 illustrates the different tube types.) Kino Flo also makes green and blue tubes specifically suited for green-screen and blue-screen work. Matte photography is discussed in detail in Chapter 17. Red, pink, yellow, and UV (black light) tubes are also available, all of which are great for decorating a set with neon-like lines of light. Sometimes, of course, a cinematographer wants to replicate the industrial green-blue look of coolwhite fluorescent lights. As often happens in art, engineers worked very hard to eliminate a vice only to have the artists rediscover it as a virtue. Gaffers commonly use commercial cool-white fluorescent lamps to get that gritty industrial look.

All Kino Flo tubes are safety coated to make the lamps more durable and ensure that no glass fragments, mercury, or harmful phosphors are released if the lamp breaks. (These parts are shown in Figure 9.8D.)

Kino Flo ballasts run at high frequency (>25 kHz), resulting in flicker-free operation at any frame rate or shutter setting. Kino Flo ballasts drive the lamps with a higher current than standard ballasts, above 800 mA (architectural lights typically run between 280 and 320 mA). Because of

this, the lights are brighter than standard tubes, they turn on instantly, operate even in very cold temperatures, require no warm-up time, and can be run with as much as 75 ft. of cable between the lamp and the ballast (most architectural fluorescent ballasts require the light to be no more than 3-6 ft away).

Because of differences in the way Kino Flo designs their lamps and ballasts, if a standard (non-Kino Flo) fluorescent lamp is powered by a Kino Flo ballast, it will have a tendency to be greener and bluer than it would powered by a commercial ballast; conversely, if a Kino Flo lamp is powered by a conventional ballast, the lamp will appear slightly magenta to the eye.

Most ballasts provide switches for individual lamps or pairs of lamps. Controlling brightness is thus a simple matter of adding or subtracting lamps, and can be accomplished locally or remotely in a number of ways that will be described shortly. Some fixtures can be dimmed by about one stop on a variac dimmer. ParaBeam and Diva fixtures have a special dimming ballast that can reduce output to 3% without flicker.

KINO FLO SYSTEMS

Kino Flo has developed a wide range of fluorescent fixtures. They can be broken down into three general categories: light fixtures with remote ballasts, light fixtures with integral ballast, and small AC/DC fixtures.

Portable modular fixtures

The original four-bank, double-bank, and single portable fixtures are among the most commonly used fluorescent fixtures on sets. Using either 4- or 2-ft T12 lamps, these extremely versatile fixtures are typically part of any lighting package. The four-bank, double-bank, or single-bank systems each has its own corresponding ballast and head cable (Figure 9.5). Kino Flo also makes 8- and 6-ft Mega-Flo systems that run on their own HO *mega-ballasts* (four-bank, double-bank, or single-bank). A more recent design, the Vista Single, also features a lightweight modular design, but uses a highly efficient 96 W CFL lamp, which is 38 in. long (Table 9.1).

These fixtures are extremely lightweight; the back and integral barn doors are a corrugated polypropylene material, and the electronics are contained in a separate power supply, not incorporated into the head. The fixture has a snap-on mounting plate for attachment to a C-stand (Figure 9.6), but because the fixtures are lightweight, they can also be taped, screwed, or stapled into place. Each fixture is equipped with a lightweight egg-crate louver that may be employed when it is desirable to control the spread of light (and it also slightly reduces the intensity). For greater control of the spread of light, *combiner clips* can be used to stack several louvers on the same fixture. The spread is reduced to 67° with one louver, 37° with two, and 25° with three.

The four-bank, 4-ft units provide sufficient output to serve as key light at fairly low light levels, or as a soft fill at higher light levels. The double-bank and single-bank fixtures are handy for hiding in sets, to glow a background wall or set dressing. The small fixtures are perfect to light actors close to the fixture. Because the fixture is small, cool, and light, it can be attached to a nearby wall, hidden behind furniture or set dressing, or built into the set.

FIGURE 9.5

The Kino Flo four-bank, 4-ft. fixture, here as part of a kit with two fixtures, select ballasts, head cables, baby stand mounting plates, and traveling case.

(Courtesy Kino Flo, Inc.)

Table 9.1 Kino Flo portable, modular fixtures

Fixture	Lamp(s)		Ballast
2-ft. Single	1	24-in. T12	Single select
2-ft. Double-bank	2	24-in. T12	Double select
2-ft. Four-bank	4	24-in. T12	Four-bank select
			Four-bank DMX512
4-ft. Single	1	48-in. T12	Single select
4-ft. Double-bank	2	48-in. T12	Double select
4-ft. Four-Bank	4	48-in. T12	Four-bank select
			Four-bank DMX512
6-ft. Single	1	72-in. T12	Mega single
6-ft. Double-bank	2	72-in. T12	Mega double
6-ft. Four-bank	4	72-in. T12	Mega four-bank
			Mega four-bank DMX512
8-ft. Single	1	96-in. T12	Mega single
8-ft. Double-bank	2	96-in. T12	Mega double
8-ft. Four-bank	4	96-in. T12	Mega four-bank
			Mega four-bank DMX512
Vista single	1	38-in. CFL	Vista single

FIGURE 9.6

The removable mounting plate.

(Courtesy of Kino Flo, Inc.)

It is important to allow for some ventilation to the lamps, because fluorescent lamps are liable to turn greener and bluer if they overheat. Gel or diffusion can be clipped to the barn doors or to the reflector, but if a fixture is completely encapsulated in gel and blackwrap, it will go off color.

Gaffers have developed their own names for these lights. You can imagine how confusing things can get when a gaffer comes on the radio and asks for "four 2-ft. 4-banks, two four-bank 2-ft. fixtures" or a "4 × 4" (which is also the term for a bounce card). For this reason, some gaffers simply say "long" and "short": "long-4" for a 4-ft. four-bank fixture, "short-four" for a 2-ft. four-bank fixture, and so on.

The light of a fluorescent tube is unique, because the linear shape of the source creates a beam that is soft. in one dimension and less so in the other. If a single tube is set horizontally, it wraps laterally, but not vertically, around the subject. The more lamps the fixture has, the more it wraps in both dimensions. Each orientation has its own applications, and some DPs even prefer put the lights on a diagonal. A ball joint in the back plate allows the fixture to be rotated and locked in any orientation.

The fixture is designed so that if the whole fixture is too bulky for a particular application, the tubes, wiring harness, and reflector can be quickly stripped out of the fixture (Figure 9.7). Bare tubes might be taped somewhere that is just out of the camera's frame: under a bar counter, on the wall, or behind a piece of furniture, for example. Taping the reflector to them increases the brightness of bare tubes. Bare tubes can be neatly mounted to a surface using plastic cable ties and adhesive cable tie mounts (and staples if necessary, as in Figure 9.8G) or by applying double-stick tape to the tube.

A special Y-splitter (Figure 9.8E and F) can be ordered that splits a four-bank (or two-bank) cable into single harnesses, so you can mount tubes end to end. Tubes are often used this way when hidden behind a bar—say, to light the bartender. Be sure to order additional single harnesses and cables with the splitter.

With all fluorescent ballasts, it is important to connect the fixture to the ballast *before* the ballast is turned on, or the electronics will suffer. Newer Kino Flo Select ballasts have circuits to protect the

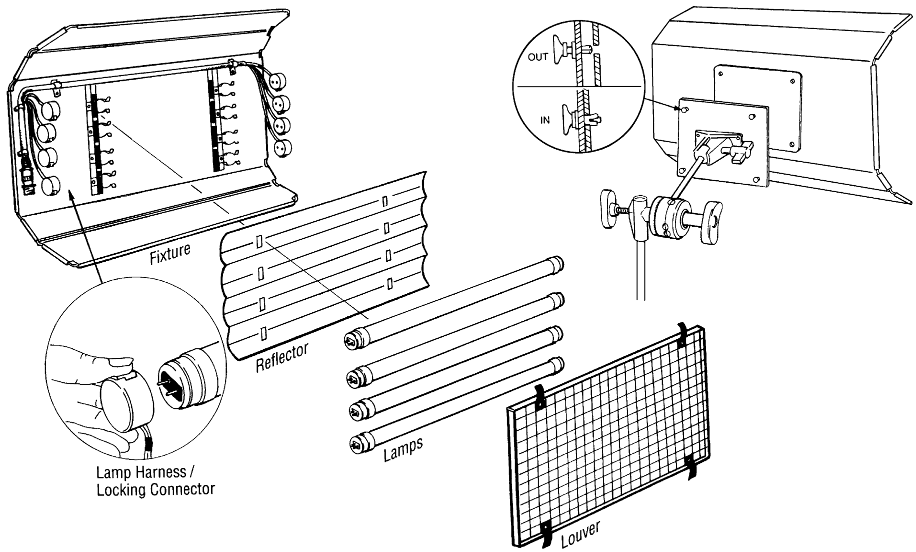


FIGURE 9.7

The components of the portable Kino Flo fixtures. The tubes can be used with or without the fixture, the reflector, and louver. The lamp harness uses a simple spring-loaded locking connector. The mounting plate pops on and off quickly using plastic locking pins. No tools required.

(Courtesy Kino Flo, Inc.)

electronics from this problem, but many ballasts do not. Kino Flo standard ballasts (four-bank, double, and single) provide either a three-position toggle selection switch (all lamps/off/half the lamps) or individual switches for each tube. Kino Flo *Select* ballasts (four-bank, double-bank, and single) feature an additional high-output/standard-output toggle switch. Use the HO setting for 4-ft. lamps and the standard setting for 2-ft. and 15-in. lamps. Operating 2-ft and 15-in. lamps at the HO setting raises the color temperature and green output. Many gaffers use this output switch also to set brightness level when needed—about a ½ stop difference.

Kino Flo DMX512 ballasts provide on/off control of the lamp switches via the standard DMX512 control protocol. At one time, Kino Flo manufactured *dimming ballasts* for their double-bank and single fixtures. These ballasts have been discontinued, but may still be rented. They feature a slider to adjust light output in a full range with no change in color temperature. A trim adjustment allows you to set and return to a particular setting easily and to turn the lamp on at a preset level. Dimming ballasts provide a jack for attachment of a remote cable.

Kino Flo portable fixtures are made with wire barn door “hinges” (the flexible metal rods at the corners of the doors), which are made to be disposable. If one breaks, it can be easily replaced by removing the end screw, pulling out the broken wire, and replacing it with a length of good wire (Figure 9.8I).

From time to time, one or more tubes in a fixture will not light. The problem could be in the ballast, the lamp harness, or the lamps. The best way to proceed is as follows:

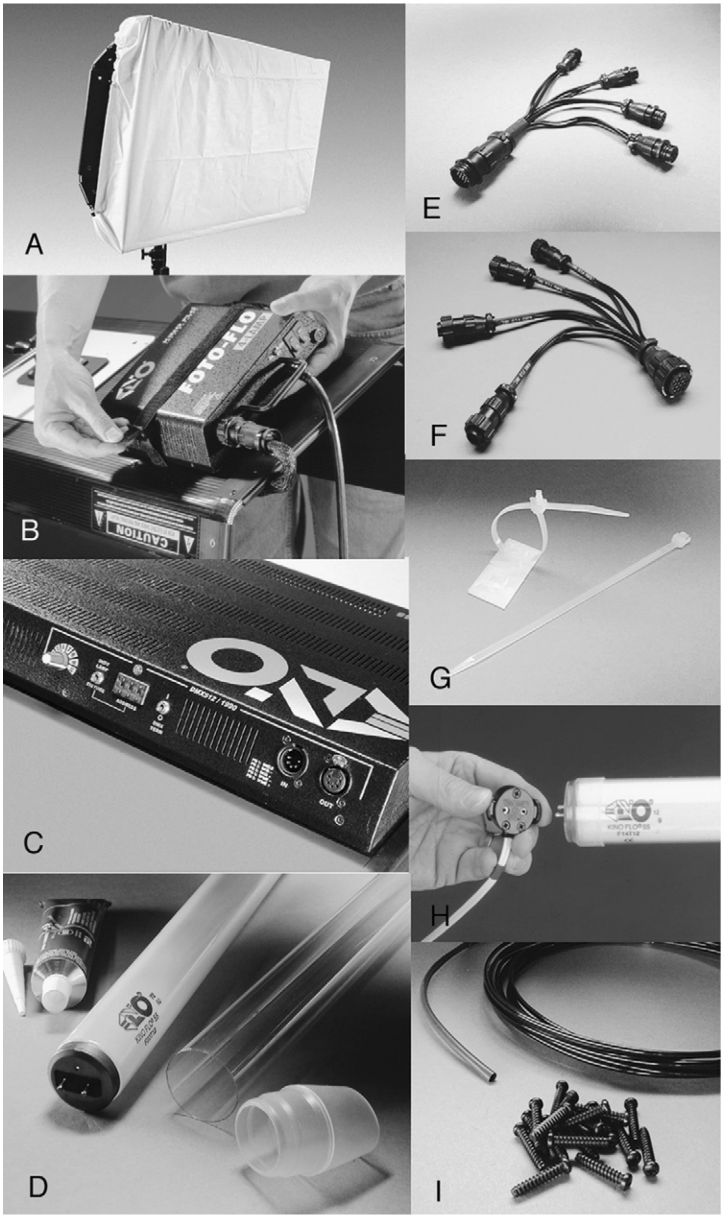


FIGURE 9.8

(A) "Flosier" diffusion on a Diva-Lite. (B) Velcro straps hold the Foto-Flo ballast to a four-bank fixture. (C) Dimmable DMX512-controlled ballast. (D) Kino tubes are sealed in plastic tubes for safety. (E) Four-bank to single splitter—it allows four tubes with single harnesses to be connected to a four-bank ballast. (F) Single to four-bank combiner—it allows four 12 V single ballasts to power a four-bank fixture. (G) Adhesive mounts and releasable ties, handy for mounting bare tubes (you can also staple the plastic mount if the adhesive doesn't hold). (H) Harness connector. (I) Barn door wire repair kit.

(Courtesy Kino Flo, Inc.)

FIGURE 9.9

Kino Flo makes a lamp tester that tests the pin socket to assure that the cathodes are intact. The tester also has an antenna, which when held against the lamp, excites the phosphors and ensures that the glass has not cracked and let the gas escape. You could also make the latter test by holding your walkie-talkie antenna against the tube while transmitting.

(Courtesy Kino Flo, Inc.)

1. Double-check that the ballast is plugged into live 120-V AC service.
2. Check that the extension is properly connected at the ballast and harness.
3. Check that the harnesses are properly secured to the tubes and the head cables are fully connected at both ends. Harness connectors are color-coded; the same color must be on both ends of the lamp.
4. Switch the ballast to full ON position. Note which lamps do not work, and try another ballast. If the same lamps still do not fire, change those lamps. If the lamps still do not fire, change the harness.

Fluorescent lamps have a relatively long lamp life; however, they do fail. It is very helpful to be able to quickly test a questionable lamp without having to install it in a fixture (Figure 9.9). When renting four-bank Kino Flos in large numbers, it is prudent to include a few extra backup four-bank ballasts (1 for every 12 systems). The Kino Flo Select ballasts have a latch-up feature to protect the solid-state circuitry from abuse during operation. However, many older ballasts are still in circulation. Single and double systems generally do not require backup ballasts.

Kino Flo fixtures with remote ballasts

Keeping with the idea of low-profile and lightweight fixtures that are remotely controllable, Kino Flo developed the fluorescent fixtures listed in Table 9.2. Especially when the light is rigged up high, it is better to have separate ballasts for ease of control, and to minimize the space and weight of the fixture. The Bar-Fly (Figure 9.10), the Flathead 80 (Figure 9.11), and the Blanket light (Figure 9.12) cover the gamut of sizes and applications. Kino Flo 12 V fixtures are commonly used in car rigs and similar mobile situations (Figure 9.13). These fixtures are listed in Table 9.3.

Table 9.2 Kino Flo light fixtures with remote ballasts

Fixture	Lamp(s)		Ballast	
Bar-Fly 100 Bar-Fly 200 Bar-Fly 400	1 2 4	12.5-in., 55 W Quad QFL	Bar-Fly 100 Bar-Fly 200 Bar-Fly 400	Separate lamps switches plus HI/LO switch Very bright, thin (2-in.), relatively small fixtures designed to be adaptable to many situations and easily hidden from the camera. The head utilizes a built-in white reflector. The ballast is capable of striking the tubes with as much as 75 ft. of cable between the two. 45°, 60°, or 90° honeycomb louver, snoot, variety of mounting plates. The head can be oriented any number of ways on the mounting plate; however, to avoid color shifts, keep the bases of the lamps either at the sides or at the top of the fixture, never at the bottom
Flathead	8	4-ft., T-12	2 four-bank select, or 2 four-bank DMX512	Separate lamps switches plus HI/LO switch Accessories include parabolic silver louver that controls the spread and direction without cutting too much light output Card holders at the corners allow a lighting technician to fabricate foamcore barn doors in custom shapes and dimensions and attach them with grip clips
Blanket Lite	16	72-in., T12	4 mega four-bank, or 4 mega four-bank DMX512	6-ft. square arrangement on a fabric base. A silver fabric reflector is mounted behind the tubes. The whole assembly is only 10 in. deep

FIGURE 9.10

The Bar-Fly 200, shown facing us with 90° honeycomb louver, measures 16 × 9 in. The 100, facing away, measures 16 × 6 in. The 400 (not shown) measures 16 × 19 in.

(Courtesy Kino Flo, Inc.)

FIGURE 9.11

The Flathead 80 fixture (51 × 24 in.) is lightweight and has high output (eight lamps). The head is connected to two Select ballasts. Card holders at the corners enable the easy use of extension doors. The detachable mounting plate swivels in all directions and locks with a knob. The mounting plate pictured fits 1⅛-in. junior receiver.

(Courtesy Kino Flo, Inc.)

FIGURE 9.12

The 6 × 6-ft. Blanket-Lite suspended in a frame with diffusion and a soft crate to control spill.

(Courtesy Kino Flo, Inc.)

FIGURE 9.13

The 12 V DC Mini-Flo 9-in. fixture can run off either a single or double power supply. Accessories (not shown) include mounting plates, armature wire to mount the light in any position, a cigarette lighter adaptor, and clip-on car battery cables.

(Courtesy Kino Flo, Inc.)

Table 9.3 Kino Flo DC 12 V fixtures

Fixture	Lamps	Ballast	Features
12 V Single	T-12 T-10 T-8	12-V DC (can power T12 lamps in various lengths: 15-in., 2-ft., 3-ft., and 4-ft.)	With the proper adapter cables, you can power a standard four-bank fixture from four 12 V ballasts. Great for mobile situations like buses, ambulances, or boats.
Mini Flo	9-in. T-8	Dimmable	Kino Flo makes 12 V "car kits" with either 15-in. or 9-in. single-tube fixtures, dimmable ballasts, all the usual accessories, cigarette lighter connector, and spring clamps to connect to a car battery.
Micro Flo	6-in. 4-in.		4-in. tubes, thinner than a pencil (either tungsten or daylight). Their size makes them uniquely suited for many special applications, such as to light a face inside a space suit helmet. They are commonly used for tabletop and miniature photography.

Kino Flo self-contained light fixtures

Kino Flo's larger self-contained fixtures, Vista, ParaBeam, Image, and Wall-O-Lite all provide DMX512 control as well as manual controls on the fixture (Figure 9.14). The smaller Diva fixtures are primarily designed to be used within easy reach and provide a manual knob for continuous dimming (Figure 9.15). Each of these fixtures has special capabilities and advantages, as outlined in Table 9.4. The Vista uses a very powerful quad QFL lamp and can be rigged in many different ways (Figure 9.16). The ParaBeam is an attractive continuously dimmable fixture (Figure 9.17). The Image fixtures (shown in Figure 9.3) are mounted on a yoke and can thus be rigged more like a traditional softlight fixture. The large dimensions of the back-mounted Wall-O-Lite make it well suited as a large key light or area light, but it is also often used for lighting backdrops and blue screens.

Some considerations when choosing the best fixture for a particular application include:

- Whether the fixture is DMX512-controllable (Image, ParaBeam, Vista-Beam, Wall-O-Lite, or any fixture using a four-bank DMX ballast, or four-bank Mega DMX ballast).
- Whether the fixture is continuously dimmable (Diva, ParaBeam, and car kits).
- The type of lamps. The newer CFL lamps coupled with Kino Flo's specially designed reflectors are much brighter than the standard T-12 lamps of a similar size. They also have very long lamp life (10,000 h). Whereas T-12 lamps are available in a wider variety of color temperatures and VFX colors.
- Whether the fixture is yoke-mounted or mounted with a plate on the back of the fixture. The plate allows the fixture to be swiveled in any direction and locked at any angle (Vista, ParaBeam, Wall-O-Lite). A yoke is placed at the lights center of gravity and is ideal for hanging the light in studio situations (Image).

FIGURE 9.14

Image 85 back panel. Controls include: ON/OFF switch, a selector knob that increases or decreases the number of lamps that are energized, Standard/Hi Output to adjust the drive current, DMX512 address interface, an IND/FIXTURE switch (which selects the DMX personality of the fixture, either INDividual control of the lamps on separate channels, or FIXture control), and on the far right a DMX termination switch OPEN/CLOSED (sometimes noted "End of the Line" on Kino Fixtures). The manual controls (STD/HO and selector knob) are disabled when a DMX512 signal is applied. Turn address to 000 to restore manual control. There is a 5 second delay when switching between DMX and manual.

(Courtesy Kino Flo, Inc.)

FIGURE 9.15

Diva-Lite four-bank (26 × 12 in.) and two-bank fixtures (26 × 7.5 in.) use integral dimming ballasts and HO lamps.

(Courtesy Kino Flo, Inc.)

Kino Flo makes a variety of accessories for their fixtures. Among the most useful of these are honeycomb louvers. The louver is an invaluable device, because it solves the problem common to all soft sources—containing the soft light that wants to spill out in all directions. The louver provides a way for the subject to receive light from the entire face of the source, yet the light is channeled and not allowed to spill sideways. This eliminates the need for flags and additional grip work, and space occupied on set. For some fixtures, the louvers are available in a variety of beam angles (90°, 60°, and 45°) depending on how much you want to cut down the angle of the beam as it leaves the fixture. When using the louver, the edge of the beam is still soft and blends easily.

Most Kino Flo fixtures can be mounted in a number of different ways. The Vista, for example, normally mounts using a center plate on the back of the fixture supported on a speed rail pipe. This can be adapted to attach to a junior stand or attached directly to speed rail using normal speed rail fittings. The center mount allows the fixture to be rotated 360° on its side to orient the lamps horizontally or vertically. However, this puts the support well behind the center of gravity of the light, so it will be quite front-heavy. If the lights are to be hung from a pipe, this has a tendency to turn the pipe. Alternately, the Vista can be supported by attaching a yoke, which connects at the center of gravity of the fixture. Corner blocks (plastic blocks at each corner of the fixture) provide a means of stacking the Vista fixtures for transport and storage. The corner blocks also provide loop holes for hanging the fixtures with rope, and slots for the gel frame and louvers to clip into the front.

Table 9.4 Kino Flo Self-Contained Light Fixtures

Fixture	Lamps		Ballast	Features
Image 80, 85	8	4-ft., T-12	DMX512-controlled plus knob on back. Hi/Lo output switch	Designed for studio applications and green- and blue-screen work. The fixtures are yoke-mounted, with metal housings, metal barn doors.
Image 40, 45	4	4-ft., T-12	Image 85 and 45 fixtures Hi/Lo output is DMX512-controllable	
Wall-O-Lite	10	4-ft., T-12	Built-in ballasts, DMX512 controllable	This is a large fixture that mounts with a back-plate and can thus be swiveled in any position. The fixture is enlisted as a large key light to create a seamless wall of light for special set pieces or matte screens. The fixture is also useful as an area light or Northlight. It mounts on a junior stand.
Vista Beam 600 Vista Beam 300	6 3	34-in. twin F96/CFL	Built-in ballasts, DMX512 controlled or via knob on back. STD/HI output	Very powerful light using new technology CFL lamps. The dimensions are not as cumbersome as the 4-ft. fixtures. Pretty much blow everything else away in terms of light output. Gel frame holds color and diffusion. Louvers.
ParaBeam 400 ParaBeam 200	4 2	21-in., Twin 55W CFL	Dimmable, DMX512 controllable	Dimmable from 100% to 5% without very much color shift. Mount from a center mount plate on the back. 90°, 60°, and 45° honeycomb louvers.
Diva-Lite 400 Diva-Lite 200	4 2	21-in., Twin 55W CFL	Dimmable via knob	Great for close up soft key light. Back-mounted lollipop attachment that adapts directly to a standard baby stand.

DMX512 CONTROL AND ADDRESSING

Fluorescent light fixtures can be controlled via DMX512 in one of two ways: either by switching lamps on and off, or by dimming, depending on the capabilities of the light fixture. The Diva-Lite and ParaBeam are both dimmable fixtures, from 100% to 3%. All fluorescent lights have some color shift when dimmed; this is the result of the change in operating temperature. However the shift is not generally noticeable when dimming by only a stop or so.

For all the other Kino Flo models, brightness is controlled by the number of lamps you switch on. If the fixture provides DMX *switching*, the control console simply turns lamps on and off.

FIGURE 9.16

The VistaBeam 600 (37.5 × 36 in.) shown here uses six very bright CFL lamps. The louver accessory helps contain the light. The Vista 300 (37.5 × 20 in.) uses three CFL lamps.

(Courtesy Kino Flo, Inc.)

For the Vista, ParaBeam, and Image fixtures, the DMX control can be arranged in one of two ways; a switch, IND/FIX, (Figure 9.14) selects either: INDividual channels for each lamp, or FIXture mode, where the consoles fader operates the light the same as the manual knob on the fixture (as the fader is moved from 0 to 100, lamps turn ON from inside to outside). FIXture mode requires only two channels per fixture: the first controls the lamps, the other controls STD/HO output. In INDividual mode, many more channels are required: one dimmer address for each lamp, plus one more address to switch between standard and high output (a total of seven addresses for the Vista 600, and four for the Vista 300). INDividual mode is really necessary only if you need to control not just the number of lamps, but specifically which lamps are ON or OFF. You would want to use INDividual control when you want to turn ON the top three lamps of a row of Vista fixtures, for example, or make a chase effect. The channel numbering can get confusing. For example in INDividual mode, a Vista 600 uses channels 1-6 to on/off the 6 lamps, and channel 7 for STD/HO. In FIXture mode a Vista 600 uses channel 1 to control all six lamps, and channel 7 for STD/HO. So even though it responds to only two channels, they are not consecutively numbered (001 and 002). Do not accidentally address another fixture to channel 007. The simplest way to organize the numbering it to

FIGURE 9.17

The ParBeam 400DMX (top) measures 24.5 × 24 in. and incorporates a dimming ballast and is DMX512-controllable. The ParaBeam 200 (bottom) measures 24 × 13.5 in.

(Courtesy Kino Flo, Inc.)

address fixtures by tens: 10, 20, 30, and so on. That way, you will avoid this mistake, and you can even switch between INDividual and FIXture mode if necessary without having to reassign fixture addresses.

As with all DMX512-controlled devices, the start address number of the unit is set using the DMX address on the light fixture. It is a good idea to do this before hanging the lights where they may be harder to get to. Note: when a DMX512 signal is detected, a yellow light illuminates above the address, and the manual operation controls are automatically disabled. To use the manual controls when a DMX512 signal is present, set the address to 000. If a fixture loses the DMX512 signal, it will default to the last command it received. Even if the dimmer board is turned OFF, the fixtures will remain ON if that was the last command received.

Usually fixtures provide a termination switch. This switch must be set to "End of line" to terminate the very last fixture on the DMX cable run. On all other fixtures on the run the switch must be set to Open (O). More on DMX termination can be found in Chapter 11.

LUMAPANELS

Lumapanels are very large, very bright, controllable fluorescent fixtures made by T8 Technology. Lumapanels are commonly used as large soft light sources to light the set, as overhead area lights or for lighting big backdrops or matte screens (green, blue). They are designed such that multiple light fixtures can be mounted to truss, side by side, to create a truly massive soft light. Lumapanels are designed to be lamped with two or more different types of fluorescent tubes (3200, 5500 K, cool white, or others) so that the various colors of light can be mixed and tailored for a particular look. Lumapanels are ideal for this task, because the fixtures provide a large number of lamps on a large number of individually controlled circuits. Additionally, on some models the circuits are continuously dimmable.

The Lumapanel DMX 47 uses 28 4-ft. T8 lamps inside a large but low-profile housing (Figure 9.18). Table 9.5 details the specifications of all the current Lumapanel models. A gel frame and louver is provided with each fixture. The built-in ballasts are custom-made; they are high-frequency, high-output, and flicker-free at any frame rate. They are power-factor-corrected, and use filtering to reduce any harmonics introduced into the power line. Each fixture requires 15 A and plugs in via a regular Edison plug.

FIGURE 9.18

This set features a wall of floor to ceiling windows. Lumapanel Model 47 fluorescent fixtures (50 × 80 in.) create soft skylight, while 20k Fresnel fixtures punch sunlight into the set.

(Courtesy Mike Bauman.)

Table 9.5 Lumapanel Fixtures

Model	Lamp	Control	Dimensions
Lumapanel DMX 47	28 bulb	DMX512-Switchable	4′ × 7′ × 5″d
Lumapanel PRO 46	28 bulb	DMX512-Dimmable	4′ × 6′ × 5″d
Lumapanel PRO 44	24 bulb	DMX512-Dimmable	4′ × 4′ × 5″d

The Model 47 fixtures can be controlled at the head using seven pushbuttons that turn on/off four lamps each. The light can also be DMX512-controlled. It has 14 separate circuits (two lamps each) that can be controlled from a single DMX channel (number of lamps increases as the dimmer level is raised), or using 14 separate channels (each pair of lamps has its own dimmer channel and they turn on at a dimmer setting of 50% or more).

Lumapanel make their own custom T8 lamps for their fixtures. Commercially available lamps also can be used. Table 9.6 gives the specs for T8 lamps.

The design concept of Lumapanel is to be able to control color and adjust and change it at a moment's notice. For example, the T8 Radiant Quartz (3000 K) has a slight bias toward green; the GE Cinema 3200 K lamps have a bias toward magenta. By lamping the units with both bulbs, a DP can fine-tune the color without having to gel any lights. For an even cooler look, some DPs like to mix the uncorrected 4100 K Sylvania lamps and 6000 K lamps. The 6000 K lamps are very cool, blue-green, and as an added benefit, they are also twice as bright (one stop) as the color-corrected lamps. Mixed lamping combined with DMX dimming gives the gaffer and DP a full range of options.

The Model 47 lights weigh about 135 lbs when fully loaded, so high-capacity stands and rigging are required. Each unit has eight handles for lifting the lights. The lights can be mounted on a yoke via senior pin. The lights can also be mounted to speed rail or truss via Proburger clamps that attach to the back of the fixture. Figure 9.19 shows the fixture rigged for moving car sequence. Four Proburger mounting points are provided on the back. Four additional ½-in. threaded (13 thread) holes are provided at the center of each of the four sides of the fixture. The fixtures can be flush-mounted side by side to create a truly massive light source using the back-mounted Proburger clamps and a system of truss and pipe.

Table 9.6 T8 lamps by Lumapanel, GE, and Sylvania

T8 Technology Color-Corrected Lamps			
Radiant Quartz	3000 K	4′	T8
Radiant Daylight	5500 K	4′	T8
Radiant Green Screen	Green	4′	T8
Radiant Blue Screen	Blue	4′	T8
GE Color-Corrected Lamps			
GE Cinema	3200 K	4′	T8
GE Cinema	5500 K	4′	T8
Sylvania Noncolor-Corrected Lamps			
Sylvania Cool White	4100 K	4′	T8
Sylvania Warm White	3500 K	4′	T8
Sylvania 3000	3000 K	4′	T8
Sylvania Daylight	6000 K	4′	T8

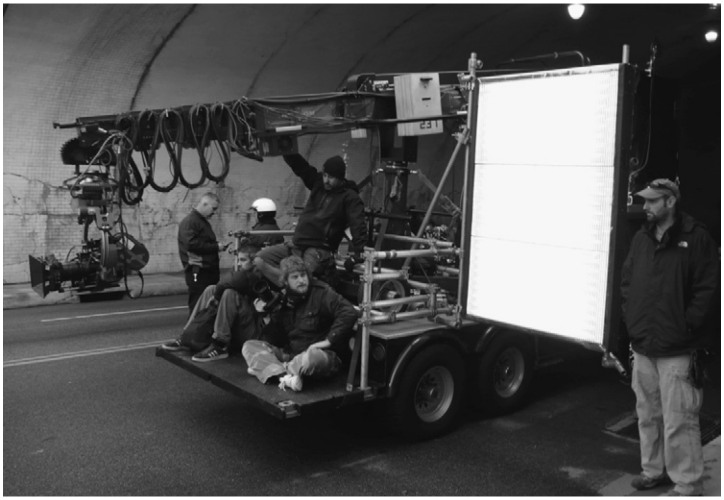


FIGURE 9.19

A Lumapanel Pro 46 mounted to the camera vehicle.

(Courtesy T8 Technology, Inc.)

If a yoke is to be used, Lumapanel recommends the following procedure for assembling and raising the light. Place the light on four apple boxes; this allows attachment of the yoke. Then insert the junior pin into a rolling turtle stand. One lighting technician foots the stand, while two others lift the light onto its feet. Place two shotbags on the yoke. This lowers the center of gravity so that the stand can roll more easily.

SOME ADDITIONAL NOTES ABOUT FLUORESCENT LIGHTS

Effect of temperature

Fluorescent lamps are sensitive to extremes of temperature. Standard fluorescents are designed for operation above 50°F. Fluorescents operating on high-frequency, high-output ballasts operate in temperatures below freezing. With all fluorescents, even those operating on high-output ballasts, the operating temperature affects both the color and the intensity of the light. Under freezing conditions, the high-intensity ballast can get the tube started, but it takes a few minutes for the tube to reach the proper color and output. In hot temperatures or if the tubes are enclosed in an unventilated space, the color may wander toward the blue-green end of the spectrum, and additional color correction may be needed.

Calculating power needs

Fluorescent lights are generally of nominal wattage and therefore pose no special power demand concerns. However, when a large number (hundreds) of fluorescent lights are to be powered, one

must keep in mind some additional factors. The wattage rating on a fluorescent tube is the power consumed by the tube alone. The ballast typically consumes an additional 10-20%. Therefore, a 40 W tube actually consumes as much as 48 W of power (20% of $40 = 8$; $40 + 8 = 48$). In addition, the power factor must be taken into account (reactive current and the power factor are explained in Chapter 13).

Most fluorescent ballasts (including Kino Flo) are not power-factor-corrected (with the exception of ParaBeam, Diva, and Lumapanel ballasts, which are power-factor-corrected). When large numbers of ballasts are used in an installation, the current present on the neutral wire will be two times the current draw of the fixtures. The neutral feeder cable may need to be doubled to accommodate this.

CHAPTER

10 LED lights

THERE'S A NEW KID IN TOWN

Everyone is familiar with LEDs—those tiny colored indicator lights that flickered on your stereo back when you were a teenager. They seem more like electronic components than lamps, and that's exactly what they are: solid-state semiconductors called *light-emitting diodes*.

In recent years, LED technology has evolved beyond all recognition. In the 1990s, the first efficient blue LEDs were developed, paving the way for RGB and white phosphor LEDs. Subsequent advances in brightness, optics, heat management, and electronic control finally made these tiny light sources viable as small illumination devices. The potential of the technology for a myriad of applications motivated huge investment in research and development of LEDs by major manufacturers such as Philips and Osram. A frenzy of commerce has followed. The companies have developed turn-key systems for fixture designers, and an ever-growing number of companies are designing an eclectic range of LED lighting fixtures for the motion picture/TV market, as well as theatrical and architectural applications.

The fact that an LED is a solid-state light emitter has more implications than one may at first realize. They are small, flat, lightweight, and require very little voltage, and so can easily be powered by battery. LED fixtures can usually be handled with bare hands (the necessity of using heat sinks allows manufacturers to control which surfaces get hot, and can keep the outer surfaces from getting scalding hot like tungsten fixtures). The emitter is a solid chunk of semiconductor; there's no lamp to break, no delicate filament. An LED is very tolerant of vibration, is durable, and has a very long useful life (50,000 hours as compared to 2000 hours, at best, for a tungsten lamp). Most LED fixtures employ a dimmer built into the power supply, controlled with onboard controls or via a digital control signal such as DMX512. LED emitters are formulated in several different colors including seven or eight narrow-spectrum single colors, and wider spectrum phosphor-based white LEDs. White LEDs range from bluer cool white emitters (daylight color balance), to warm white emitters (with a correlated color temperature closer to that of a tungsten lamp).

As is commonly the case when a new technology comes to the market, the marketing of LED products puts a little spin on the scientific data, which has a tendency to cloud the real issues like lumen efficiency and energy savings, color rendering and color temperature, useful life, and so on. There is truth in the claims, but there is also often more to the story. Fixture manufacturers like to market LEDs as super-power-efficient, "green" (meaning environmentally friendly) light fixtures. However, it has turned out to be much more difficult for fixture manufacturers to realize anything close to the kind of lumen efficiency that the LED manufacturers publish for their emitters within

Set Lighting Technician's Handbook, 4e. DOI: 10.1016/B978-0-240-81075-1.00010-6

the framework of a practical light fixture. This is especially challenging when the light fixture's purpose is lighting motion picture photography, where color spectrum, green bias and the quality of the light are subject to close scrutiny.

Like any light source, each LED fixture has unique properties that offer certain advantages in particular applications, and it has limitations. Some fixture manufacturers have made a substantial commitment of energy and resources in R&D and have made enormous strides in addressing the limitations. For other manufacturers the key to success is downplaying the limitations and keeping the price down. All this is simply to say that for the DP or gaffer attempting to understand these new tools of the trade, having a little knowledge of the technology, and a little experience with it goes a long way to sorting out the true advantages and disadvantages of using a particular fixture.

This chapter provides an introduction to the issues inherent to LED lights, and surveys some of the most promising light fixtures currently on the market. However this technology changes quickly. In accordance with Haitz's Law, it is estimated that every decade LEDs decrease in cost per lumen by a factor of 10, and simultaneously increase in efficiency by a factor of 20—that's a gain of about 2.5 times every 3 years. There is really no way to provide up-to-date information in a book. The best way to stay abreast of the technology is to follow technical trade periodicals that provide unbiased articles about the technology on an ongoing basis. Links and recommendations can be found on the *Set Lighting Technician's* Handbook Web site.

Manufacturers have come up with many ways to use LED technology in illumination devices. The common types are pads, small panels, lens lights, ring lights, larger panels, and RGB color washes. In addition there are small theatrical lights or entertainment venue lights, and a wide variety of architectural lights in various shapes and sizes. We shall look at examples of each of these types in the pages that follow. Let's first look at how LEDs render color, and some different approaches LED fixture manufacturers have taken to managing color.

COLOR RENDERING OF LEDS AND LED LIGHT FIXTURES

A central dilemma for all LED fixture designers is how to manage the color spectrum of their fixtures. This turns out to be a complex puzzle to solve, and one that distinguishes the different fixture designs. One can consider LED light fixtures in three broad categories.

1. Phosphor-based white LED (single chip), or blended white LEDs (two different white emitters, coolwhite and warmwhite).
2. Multichip, wider color gamut, LED systems (a mix or five to seven colored emitters, or white and colored emitters).
3. RGB color systems (red, green, and blue), and RGBW (red, green, blue plus white) or RGBAW (red, green, blue plus amber).

A phosphor-based white LED is the type of LED most commonly used in lighting devices for the motion picture/television market. A "white" LED comprises a die (diode chip) that creates blue or UV light. A portion of this blue light is used to activate a phosphor layer, which transforms the light from shorter wavelengths to longer ones (the difference in wavelength is known to physicists as the Stokes shift). Stokes fluorescence is the same process used by the phosphor coating of a fluorescent tube. Phosphors of different colors are applied to the die to broaden the spectrum and improve color

rendering at the yellow end of the spectrum. If you look at the spectral power distribution of a white LED you will notice a big spike at about 465 nm (the blue LED) and a broader hump between 500 and 700 nm, produced by the phosphors (Figure 10.1A). Obviously this spectrum is quite different from an ideal black body radiator (a continuous spectrum).

Depending on the chemistry of the phosphor used, the color balance of the resulting light can be correlated to daylight, or stretched closer to a tungsten color balance. The cooler white LEDs use semi-transparent phosphors so the blue "pump color" comes through. In contrast to blue LEDs, amber LEDs are opaque to the pump color, and are therefore much lower in efficiency. This Stokes process reduces the total output, so there is a tradeoff in lumen output with warmer color temperatures and broader spectrum white LEDs. Market competition often focuses on brightness, so some fixture designers opt for brighter LEDs with unappealing color characteristics, but most have tried to find a reasonable middle ground. Those that are most concerned about color performance select LED chips with better color characteristics and rely on good optical design and drive electronics to produce reasonably good output. With all these factors in play, it would be quite misleading to judge the quality of an LED fixture strictly on the basis of brightness. All designers are forced to balance these competing priorities, and each approaches it in their own way.

In the manufacturing process, there is a fair amount of variation that is unavoidable even within a single batch of LED die. LED manufacturers use a process called *binning* to systematically divide up their LEDs based on performance criteria such as flux (output), correlated color temperature, and green/magenta bias. Fixture manufacturers generally rely on careful binning practices to provide as accurate and consistent color performance as they can. Binning has been refined over the years, and these days the tolerances of the best binning systems allow barely perceptible differences between LEDs from a selected bin. The difference in color between two sources is quantified using

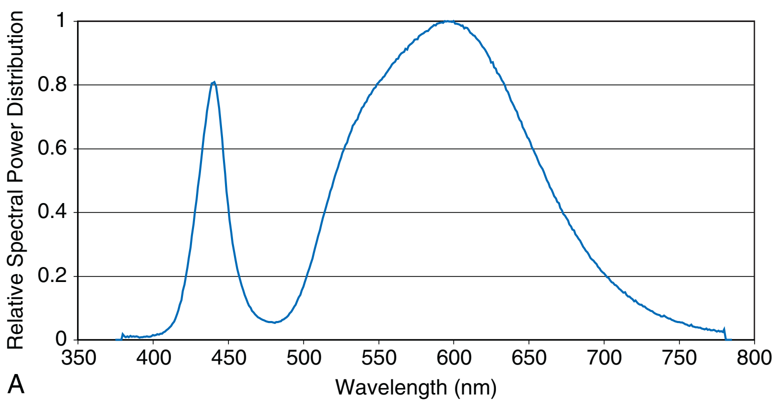
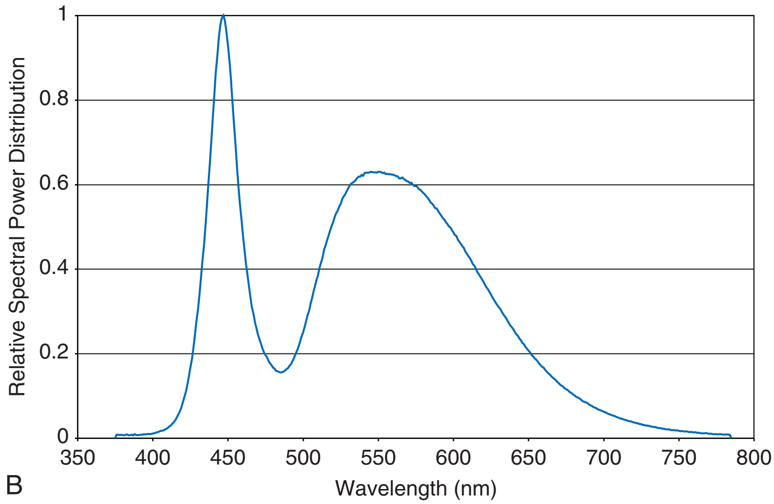


FIGURE 10.1

Spectral Power Distribution various LEDs. (A) and (B) show LUXEON Rebel LXML. (A) 3000 K LED with a CRI of 85 or higher (LXML-PW31).

Continued



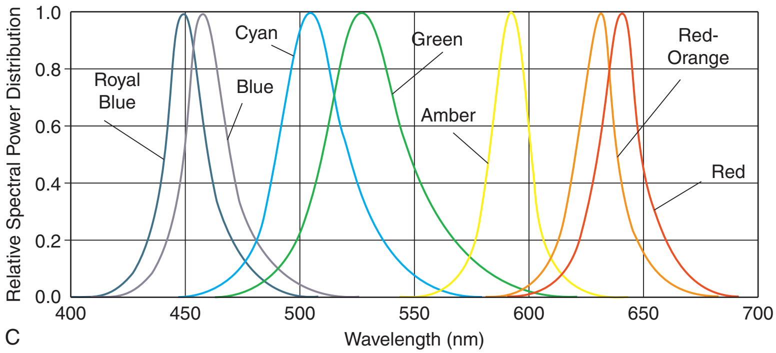


FIGURE 10.1—CONT'D

(B) This distribution describes two daylight balanced LEDs: both the 5000 K (LXML-PW31) and 5700 K (LXML-PW21). (C) Using different chemistry manufacturers have created seven or eight pure LED colors. By additively mixing colored light a wider gamut of colors is possible. (A and B courtesy Philips Lumileds. Illustration C courtesy of Mike Wood, Mike Wood Consulting Originally published in *Protocol*, the journal of *ESTA*)

the *MacAdam ellipse*. A MacAdam ellipse defines the distance at which two colors that are very close to one another first become distinguishable to the human eye as different colors. (Imagine a given color as a point on a chromaticity diagram. The MacAdam ellipse defines the contour around it, where the colors that surround the point are no longer indistinguishable from that of the point.) LED manufacturers can now bin their LEDs to separate LEDs to within two to four MacAdam ellipses. In other words, the LEDs within a single bin may be as much as four distinguishable separations apart from one another. To complicate things further, LED suppliers charge a high premium to

fixture manufacturers who buy from just one bin. To be more cost effective fixture manufacturers must mix LEDs from a range of bins. This has prompted some manufacturers to create recipes using computer modeling. For example, for each LED from a slightly green bin, the recipe compensates with an LED from a similarly magenta bin. This way the fixture designer can assure that the sum of the light from all the LEDs in each fixture falls within their prescribed parameters for color balance and green/magenta shift. For a daylight-balanced LED fixture a well-designed system can yield a light fixture having very respectable tolerance—±50 K.

Nonetheless, no white LED produces a spectrum that is continuous, or complete (as shown in Figure 10.1) and they can register a slight green or magenta bias when photographed. At this writing, LED fixtures with only one or two phosphor-based LEDs are not comparable to the best fluorescent or arc discharge (HMI) sources in terms of full spectrum color rendition. To help in evaluating if a white-LED fixture is appropriate for a particular application, let's discuss their specific limitations. White LEDs have no output at wavelengths shorter than about 425 nm, which means that violet colors on illuminated objects don't render well, even with the coolest-white LEDs, which makes them very different than daylight and other high-color temperature white sources. There is minimal output in the medium blue-cyan-turquoise range from about 465-510 nm, which not only makes it difficult to render those aqua-type colors on illuminated objects, but also skin tones and warm, amber-yellow colors don't stand out well for lack of a complementary color within the spectrum. The long-wavelength cutoff is in the high-600 nm range. Compare this with tungsten or daylight, which both extend all the way out on the long-wavelength end, and it's understandable why pinks, reds, oranges, and other long-wavelength colors tend to look a little washed out under white LEDs, compared with how they look under more conventional lighting. Multicolor LED fixtures can compensate somewhat for this problem by including more red and red-orange LEDs (between 610 and 650 nm) in the color mix, but it is difficult and very inefficient to do this with phosphors alone.

Of course, while they are less than perfect at reproducing parts of the color spectrum, white LEDs are nonetheless adequate for many tasks. For a specific application an LED fixture can offer unique advantages over conventional lights, which may outweigh the shortcomings. In applications where color rendition is *critical*, an LED light would not be the best choice. However in mixed lighting situations the color deficiencies may not even be noticeable.

Unfortunately it is very hard to judge with your eye how an LEDs spectrum is going to line up with the sensors in the camera. Eye response and camera response can be quite different. Additionally common color meters, like the Minolta III F, are completely useless with LEDs. The meter makes its calculation of the color temperature based on an assumption that the light source has a continuous spectrum. Color readings of an LED have been shown to be misleading for both correlated color temperature and green/magenta shift. A little experience is very helpful when it comes to predicting how colors will translate on film or video. Of course if you have reason to be concerned about it, it is best to shoot a side-by-side comparison using a color chip chart and a full spectrum light source.

Many fixtures incorporate coolwhite and warmwhite LEDs within the same fixture, and provide a control to mix the colors as needed. The idea is that by mixing the two sets of LEDs, the user achieves a nominal correlated color temperature of any color temperature from tungsten to daylight. This is a quick and easy, intuitive solution to color balancing that eliminates the need for fractional CTO and CTB color correction gels to achieve an intermediate color balance, which is very often desirable in mixed lighting situations. This approach does entail a compromise however. If you were

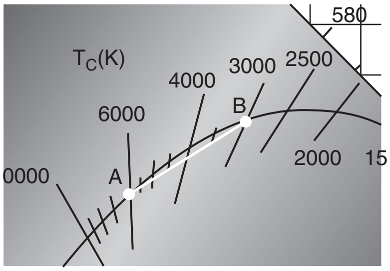


FIGURE 10.2

If you plot the color points of the warmwhite and coolwhite LEDs, a straight line drawn between the two color points (A and B) represents all intermediate colors that can be achieved. Because the locus of a black body radiator is not a straight line, it is not possible to track the locus exactly using only two color illuminants.

to plot the color point of two illuminants, all the colors that are possible by mixing the two colors of light will be located on a straight line drawn between the two points (Figure 10.2). However the black body line is not a straight line, so it is not possible to create light that remains neutral in terms of their green/magenta shift, while mixing only two colors. Theoretically if the LEDs' color points were exactly on the black body locus, the color would shift toward pink when mixed together. Whether this slight shift presents a problem in practice is for the user to decide.

It is a relatively simple matter to put a dimmer on an LED, and blend two different color LED chips to achieve variable color mixing, but it is quite a different matter to track the color so that it remains on the black body locus at every point from daylight balance to tungsten balance. It is an added challenge to maintain a specific color temperature at a high CRI *while dimming*, because temperature in the LED changes when they are dimmed. Change in temperature shifts wavelength as well as efficiency, and different LED chips change efficiency at different rates and at different temperatures. A few manufacturers have taken a far more complex approach in order to control all these factors. They start by incorporating more colors of LED chips into the fixture in order to counter the shift in green/magenta bias as the color tracks along the black body locus. The chips are controlled by microprocessors using algorithms to continuously regulate the intensities of the different colored LEDs so that the mixed light gives the desired color temperature at any dimmer setting. Using multiple LED colors within a white-light fixture increases the total color space achievable by the light, and in this way greatly improves on the limited color rendering of white-phosphor LEDs when used alone. Using this approach also allows the manufacturers to calibrate each fixture at the factory to compensate for any differences in the color output of the particular LEDs. While this approach yields the best results in terms of color, the necessity of blending the LEDs (using a frosted optical element) comes at the cost of some light output.

On the other hand there are many LED fixtures that do not concern themselves with white light at all. Because LED chips are available in pure colors, many fixtures are designed for creating dramatic color washes on walls and backdrops, or on the acting area itself. Many theatrical and architectural LED fixtures incorporate RGB chips that mix levels from red, green and blue chips (either in a single module, or separate emitters) to synthesize a range of vivid colored light. When controlled from a control console, RGB-style fixtures can create dynamic changing color effects and washes with ease.

RGB fixtures are not able to adequately produce white light. However RGBW fixtures can do a reasonable job when the white being mixed is close to that of the white used in the fixture.

In order to better understand the strengths and weaknesses of RGB lights it is helpful to look at their *color space*. The color space of an RGB fixture can be represented on a CIE diagram by plotting the color points for the red, green and blue LEDs as shown in Figure 10.3.

While RGB additive color mixing theoretically produces millions of colors, all reside within this triangle. There are popular colors like Congo Blue or a rich amber that are simply outside this color space. An RGB fixture easily creates saturated colors that a very close to red, green and blue, but the colors in-between are not achievable as saturated colors and the light is weaker and color somewhat muddier. RGBW fixtures also include a white channel. RGBA (or RGBAW) include an amber channel. This helps in a couple ways, it helps in creating pastels and tints and it broadens the color space in the yellow area. The amber makes a huge difference for mixing warm whites that do not look "dead" on skin tones.

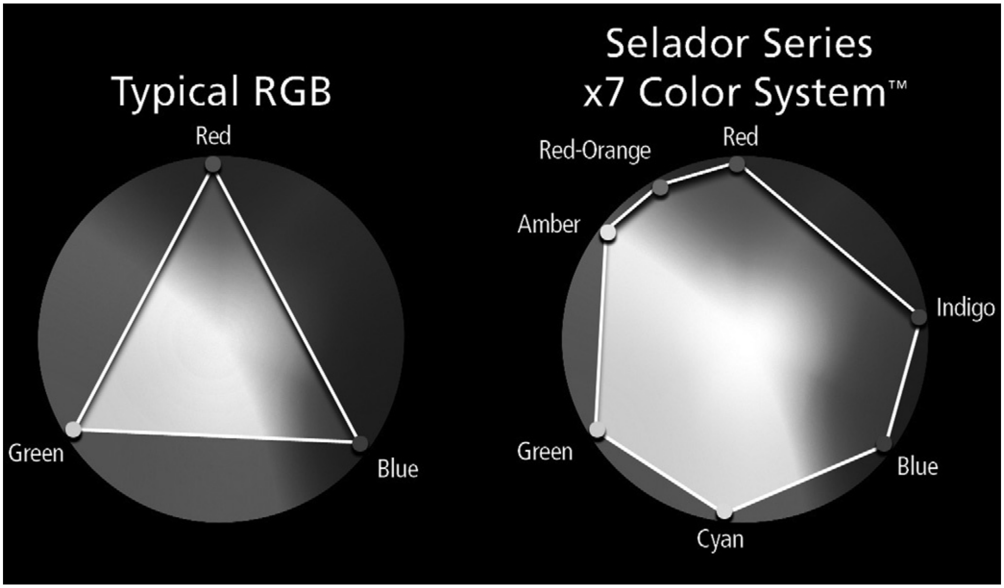


FIGURE 10.3

(On left) All colors achievable by an RGB LED are encompassed within the triangle formed when the colors of the LEDs are plotted. This is the *color space* of the light fixture. The points closest to the outer edge of the diagram are the most saturated colors. The color mixes achievable between red, green, and blue are less saturated (further from the outside edge), and have less intensity. (On right) Adding more color illuminants increases the gamut of achievable colors, and provides saturated colors between red, green, and blue (cyan, orange, and amber). More complex color mixes are also possible. This approach comes much closer to achieving a full swatchbook of colors.

(Reproduced by permission of Electronic Theater Controls, Inc.)

A couple of lighting manufacturers have developed fixtures with a greater number of LED colors in order to create a larger, more controllable color space. Comparing (Figure 10.3), you can see the difference in color space between an RGB fixture and ETC's Selador fixture, which employs seven different colored LEDs. Several fixtures on the market use this strategy to broaden the spectrum of color, and/or to mix white light.

LED FIXTURES

Pads

While LED fixtures all tend to be thin, Rosco's LitePads™ are the thinnest of all—only 8mm thick (Figure 10.4). Daylight balanced LEDs (6000 K) feed light edgewise into luminescent sheets of frosted white Plexiglas that Rosco offers in squares, rectangles and circles in a range from around 3- to 24-in. across. Custom shapes and sizes can be manufactured at Rosco including complex geometric shapes. The maximum size is 48 × 96-in. A light pad can be easily hidden or placed in hard-to-light nooks and crannies of set pieces, the dashboard or ceiling of a car, taped to the screen of a computer monitor or TV, or just taped to the wall of the set. They typically come in a kit, which includes a 12 V power supply, 12 V car lighter adapter, Y-splitter, and extensions.

Small panels

White light LED fixtures

Every gaffer has a light which is a "panic light"—the light you can grab at the last minute and handhold during a shot to add just a little light where otherwise shadows would have been too dark, an eye sparkle that brings life back into a face, a touch more exposure on an important detail where the light has fallen off. Small LED lights are ideal for this purpose because they can be

FIGURE 10.4

A LitePad kit comes with a host of accessories including stand-mount brackets, dimmer, 12 V transformer power supplies, 12 V battery pack, extension cables, filter packs, car adapter. The 6 × 12-in. pad puts out about 21 fc at a distance of 2-ft. (high output (HO) model).

(Product image supplied by Rosco Laboritories, Inc.)

gripped in one hand, are self-contained with no cables, battery-powered typically for an hour and a half or more. They emit soft directional light, and are easily controllable via a dimmer knob on the head.

Litepanels' Mini (or MiniPlus) and Micro fixtures were some of the first LED panel lights to hit the market (Figure 10.5): they are dimmable from 100% to 0%, are available in either daylight or tungsten color balance, and have a slot for fitted color correction gels. As is typical of many small LED units they can be run on a clip-on battery, an AC power supply, camera battery, or car battery. The MiniPlus system even has an available adaptor plate to run the light from two DV camera batteries.

Another common feature for a small panel light is an attachment to mount onto a camera as a lens light. Lens lights are most commonly used by fast moving video crews—news programs, promotional interviews, or industrial or documentary productions—but they are also used on films and TV shows. They are sometimes used when the camera is mounted on a crane, or Steadicam, or when the camera is operating in a narrow hallway, tunnel or cave, where there are few lighting positions available and a little fill light is necessary. Having a lens light that is infinitely dimmable without appreciable change in color temperature is a big time saver.

The Nila lighting system is an innovative LED system that incorporates a system of interchangeable lens panels (Figure 10.6). The light projected by each individual LED is controlled with a transparent optical element that focuses the light. You can do a great deal to change to size and intensity of the beam depending on the optics you use. Any one of six different lens panels may be fitted to the front of the Nila light with a single Alan bolt. With no lens the beam spread is 120°.

Nila heads are available with either daylight or tungsten balanced white LEDs. A Nila daylight with flood lens gives 32 fc at 10 ft. With the spot lens it gets 180 fc at the same distance. Of course the light from spot optics (of any fixture) is harsher in appearance. The Nila fixtures are designed to lock together (via dovetails in the sides), so two, three, four, or six heads can fit together as a single fixture attached to a yoke and hung or mounted to a light stand.

Accessories include specially fitted gels, barndoors, chimera brackets, eggcrate (either 15° or 30°). A Nila kit normally includes a variety of different size yokes to accommodate single, double, and triple head arrays (bigger yokes for more heads are also available). Each Nila head has 3/8-in.

FIGURE 10.5

Litepanels MiniPlus.

(Courtesy Litepanels, Inc.)

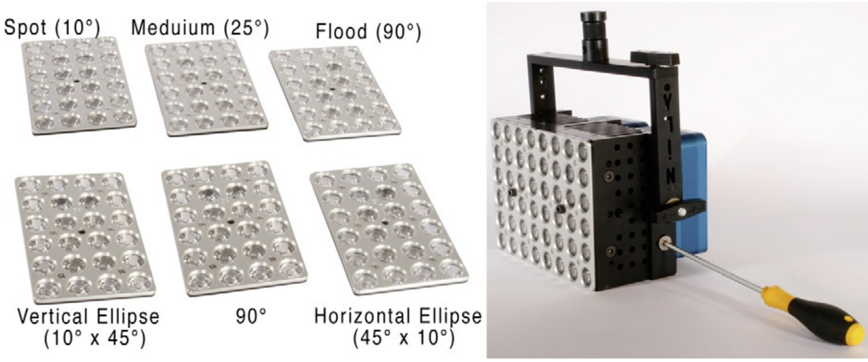


FIGURE 10.6

The Nila light has six interchangeable lens sets. Here two fixtures are locked together side by side and the appropriate size yoke is attached. A $\frac{3}{16}$-in. Allen wrench is used for lens changes and yoke changes. When stacked, the dimmers of all the heads can be slaved to a master light (using RJ45 jumpers between the heads), for central control.

(Photos Courtesy Nila.)

(16 thread) holes on either side of the fixture. This provides for any rigging option; you can screw in a baby stud or eyebolt. It uses an onboard autoranging universal power supply 90-240 V AC or DC, or a battery. With an adapter, up to six Nila lights can run off a car battery. The built-in dimmer is DMX512 controllable (A jumper cable has an RJ45 connector to connect to the fixture. The other end connects to a Nila's opto-isolated DMX box). You can also use a hardwired remote hand dimmer accessory, that plugs into the fixture. Nila also makes a video flicker generator accessory. This is a box that uses a video signal to generate the flicker pulses for the lights—the reactive lighting perfectly mimics the light from the video image.

The fixtures described thus far use either tungsten or daylight balanced LEDs. However there are also small panel fixtures that can do both, and can blend warm with cool light to suit the needs of the shooting environment. The Blender light is a small (4.5 × 3-in.) light commonly used as a lens light, which incorporates 3100 and 5500 K LEDs with separate dimmer controls.

The Caster series of lights (LoCaster and BroadCaster) made by ARRI also provide a broad range of color temperatures, however their approach is quite sophisticated. ARRI's fixtures are actually a kind of hybrid fixture—a white light LED that uses three different LED chips to expand the color gamut, maintain a high CRI throughout the range of color temperatures, and actively neutralize green/magenta shift as well. With substantial R&D ARRI's engineers were able to arrive at a design that maximizes white light output while maintaining subtle control over color rendering. The Caster lights actually employ blue, red, and white LEDs that have some green in them. A microprocessor controlling the drive current to the LEDs employs software algorithms to readjust the relative strengths of the three colors to compensate for color shifts.

While the technology is quite sophisticated, the interface is simple (Figure 10.7). On the back of the LoCaster fixture one knob provides a choice of six color temperatures (2800, 3200, 4000, 4800, 5600, and 6500 K) with the CRI maintained at 90. A second knob provides dimming from 100% to 0%

FIGURE 10.7

ARRI LoCaster The Caster series takes 11-36 V DC so it can be run off a camera battery, car battery, or AC power supply. Accessories include an aluminized intensifier (a tapered hood that fits to the front of the fixture to concentrate the beam and enlarge the source), 2-leaf barn doors, 2-leaf egg crate. A threaded hole on the back of the fixture provides a rigging point for a baby pin a camera's hot shoe or other rigging.

(Courtesy ARRI Lighting.)

without a shift in color. The LoCaster fixture can use a 60 W mains power supply, a small 30 V NiMH battery pack, or 12 V car adaptor. The LoCaster fixture is designed to be controlled at the head (Lo stands for location).

The ARRI BroadCaster is the same light fixture as the LoCaster, but with full DMX512 control capability.[1] Each fixture uses three channels (a fourth is reserved for future functions). The three channels control: (1) intensity (0-100%), (2) color temperature (2800-6500 K), (3) ±green shift. The DMX512 signal cable from the console or DMX512 controller plugs into a 300 W power supply, which provides control signal and power to up to six heads via a Power/DMX 4-pin XLR. You set the DMX address of each light on the individual BroadCaster heads. The power supply provides three 4-pin XLR outputs; up to three heads can be daisy-chained to each output. A blue indicator light shows the presence of a DMX512 signal. A green indicator light signifies proper voltage to the head.

LED emitters age extremely quickly if they are operated over temperature. Both Nila and ARRI incorporate a protection circuit, which shuts the light off in the event of overheating. A red indicator light signals an overtemp situation. You reset the circuit after cooling by disconnecting and

[1]The LoCaster fixture is also DMX controllable. This can be done using a Y-cable accessory (which combines power input with standard DMX512 signal input (5-pin XLR) and provides a four-pin XLR that connects to the head), or using the 300W DMX power supply. However the LoCaster does not have addressing capability. If multiple LoCaster fixtures are connected to a DMX512 signal they respond to channels 001, 002 and 003 with the behaviors described above, but they all respond together, and cannot be separately addressed. Conversely, to some extent the Broadcaster head can be controlled at the head by selecting addresses above 900 to select from preprogrammed color temperature presets.

reconnecting the head. ARRI recommends against using the light pointed straight up for prolonged periods in order to provide adequate convection cooling for the heat sink.

ARRI PAX panel kit

ARRI in cooperation with OSRAM created the LEO chip—five different color chips within a single emitter. Eight LEO modules are used in each PAX panel light. The user can select any color temperature white light (from 2000 to 20,000 K), can finely tune the color with a green/magenta bias (or skew the green/magenta parameter as you wish), *and* can also dial in colored light using hue and saturation controls, or select a particular gel color from the internal database.

LEO is a multichannel microprocessor-controlled LED light engine with algorithms working in the background controlling light output, color and CRI. These algorithms take into account fluctuations in the color output of the chips due to changes in the dimmer setting or ambient temperature—the two main variables that throw off the color of electronic lights.

Each panel is equipped with quick-change soft (115°) and spot (22°) optics that fit to the front of the lights held firmly with magnets. The spot optic can be modified using a variety of beam shapers.

This system comes as a kit with multiple heads and a central control unit (Figure 10.8A). The wireless (or hardwired) master controller (Figure 10.8B) provides complete control over color output for up to four fixtures. The PAX panels run on a battery pack that clips to the backs of the panels so the lights can be powered and controlled completely remotely. The wireless feature is handy when the light flies on top of a moving camera, and it is always convenient to be free of cables.

The master controller offers the following functions:

- Exact dimmer setting from 0% to 100%. As the light is dimmed, the microprocessors maintain the exact color settings.
- White light mode:
  - Dial in any color temperature from 2000 to 20,000 K. When operating between 2000 and 6500 K the CRI is automatically maintained above 95.
  - Dial in ±green. To match to green or magenta sources (or skew the green/magenta parameter as you wish).
- Colored Light mode:
  - Hue and Saturation dials
- Filter Mode.
  - Select any Rosco or Lee gel color using the large dial; select it by pressing the dial.
  - You can combine the gel with either a tungsten or daylight source by toggling back and forth with the FILTER button.

The wireless transceiver also attaches directly to the panel on one end. Alternately, one panel may be attached directly to another one, either end to end, or one on top of the other (by using a panel-to-panel adapter) and both are then controlled from a single transceiver. The kit may also come with an optional item called a Mini Controller—a pocket sized control device with a more limited range of features that lets you control one panel using dimming and preset color temperatures (3200, 4300, 5600, 6300 K and two user defined presets).

The PAX is like an entire swatch book of colors at you fingertips. One DP uses the light to preview gel colors for the director during prep. While looking at gel swatches he is able to shine the

FIGURE 10.8

(A) ARRI Pax Panel Kit, The PAX Panel lights are small enough to be used as an on-camera light, an eye light, a warm beauty light, a cool accent light. Their size is also ideal for product shots, and miniatures. They can be easily hid in a set to create colorful accents. They can match to any practical source such as a green fluorescent, a pink neon sign, a blue TV screen light. (B) The Master Controller has four user memory buttons for storing settings. These presets are not lost when the controller is switched off. The controller can also be controlled via DMX512 from a control console using a system junction box to tie the two together. This allows infinite potential for recorded presets and dynamic light effects. The DMX addresses, dimmer law, wireless channel, and similar system preferences are accessed via the SETUP button.

(Courtesy ARRI Lighting, Inc.).

colored light and see how a particular gel color interacts with someone's face and hair, wardrobe and fabrics, paint samples and furniture. Using two panels he can see what happens when two gel colors interact. The PAX panels transceivers and controllers can be updated with new software as new options are developed.

Larger panels

White light panels

Larger LED panels use dozens, even hundreds of LED emitters to create a large light source capable of being a primary light source at moderately close range. Litepanels makes its 1-ft square fixtures, called 1×1 seconds. Gekko makes a roughly 1-ft. × 2-ft. fixture called karesslite. The panels are typically either coolwhite (5600 K), or warmwhite (3200 K) balanced. Litepanels Bi-Color 1×1 fixture combines 5600 and 3200 K LEDs (Figure 10.9). The color mix knob is not indexed, so to set a repeatable color temperature you enter it using the DMX address interface. Set the first number in the address to 8 and the other two to the Kelvin temperature you want: 832 for 3200 K, 845 for 4500 K as so on.

Most large panels offer DMX512 as an option. Because the dimmer already exists in the fixture, you should not plug an LED fixture into a dimmer line (a triac household dimmer, variac or SCR dimmer) unless the fixture manufacturer specifies that it can be used in this way.

FIGURE 10.9

1×1 BiColor Litepanels. The two sets of LEDs are controlled on the back of the fixture by two knobs: one dials the color mix; the other is an overall dimmer.

(Courtesy Litepanels, Inc.)

Even the larger LED panels often can incorporate a clip-on battery, useful when a self-contained unit is desired. Some panels are designed to be joined together using mounting accessories to make a larger source. Four 1-ft square fixtures can be ganged to become a 2-ft. × 2-ft. lighting source, or 16 can be ganged to become a larger, softer, more powerful 4-ft. × 4-ft. source, a feature available for both Litepanels and karesslight. The Litepanels housings provide numerous 1/4-in. (20 thread) holes for mounting 1×1 seconds to a frame material of the user's choice. Typical accessories include ball-mount base plate and other mounting hardware, remote dimmer control, car cigarette lighter adapter. Egg crate louvers are also available.

Litepanels 5600 K 1×1 panels use permanent optics, but fixtures are available as flood or spot units. Employing flood optics, the 1×1 puts out a very serviceable 30 fc at 8-ft. The spot lens version of the same light generates 45 footcandles. To give some point of reference, a 4-ft. Double-bank Kino Flo puts out 26 fc, the 4-ft. 4 bank puts out 49 fc at the same distance.

Light fixtures made by Color Kinetics originally for the architectural market have been adopted into entertainment lighting, and are now marketed to the entertainment industry. Their Intelligent White (iW) fixtures, notably the iW Blast and iW Reach are powerful fixtures with adjustable color balance (using warmwhite and coolwhite LEDs). The fixtures are controllable via DMX512 to provide correlated color temperatures from 2700 to 6500 K, as well as dim control. Both fixtures have a wide variety of spreader lenses and accessories. The iW Blast is about 13-in. in length. CRI is reported around 83 (74 with only the coolwhite LEDs). The Reach is a larger fixture (about 21-in. × 29-in.) with very powerful LEDs putting out some 10,000 lumen with no spread lens. CRI is reported as 68.5. The fixture is in two halfs so that the upper half and lower half can be fitted with different lenses and controlled separately via DMX512. This allows for large-scale wall washing, with the upper half using a narrow lens, and the lower half using a wider beam angle.

Kelvin Tile panels

The Kelvin Tile™ is an LED fixture, roughly 1-ft square, designed originally by Element Labs and Kino Flo. Internal software controls a blend of six calibrated color LEDs (red, green, blue, cyan, amber, and white). By mixing varying amounts of the six LEDs and blending the light with a special diffusion material, the Kelvin™ Tile achieves a full spectrum with high CRI, and can do so in any color balance, from 2200 to 6500 K. It can be dimmed from 100% to 1% with no color shift. An algorithm in the microprocessors compensates for the effects of dimming to maintain the desired color. (At this writing the Kelvin Tile is not designed to create pure colors.)

A look at the Kelvin™ Tile's back panel shows its primary array of tricks. It has presets for selecting 3000 and 5600 K, or you can dial it to any color temperature by eye. A dimmer knob provides manual control of brightness (without any color shift).

A Kelvin™ Paintbox, a programming accessory that plugs into the Kelvin™ Tile, provides additional functionality. It has a display that shows the exact parameters you have selected. You can use the display to dial-in a specific color temperature and adjust green/magenta bias by standard increments (⅛, ¼, ½, and full). The paint box allows the user to scroll through a large number of color presets. It saves and recalls color parameters for up to eight fixtures at a time. The color parameters can be cloned from one fixture to another. It provides "digital gelling," allowing the Kelvin™ Tile to match any Lee or Rosco color-correction gel color (CTOs and CTBs). Both the Kelvin™ Tile and the Paintbox can be updated with new software as new options are developed.

Ring lights

A ring light is a circular light fitted to the camera lens so that the camera shoots through a hole in the center of the light. This very frontal lighting lifts facial shadows. It lights into the eye sockets, fills facial wrinkles or blemishes. Depending how it is used it can create big bright circular reflections in the eyes and reflect off of lipstick or facial sheen. Ring lights are sometimes used to create a certain glamour look. A ring light can be very handy when the actor is close to the lens. Often there is simply no other way to get light onto the face because the camera is in the way. A little fill light from the camera avoids the actor falling into a black hole that gives away the presence of a camera. A ring light can also be used simply as a glorified Obie light, or frontal key. Very often we will shoot an actor looking into a computer screen, or into a mirror or other luminous source, having the actor looking right into the camera. In such a case it is necessary to have light emanating from that direction. To give another example, when the camera is crane-mounted or flown on a Steadicam, the camera might travel some distance before landing on a close-up of the actor's face. There is no place to put a light for the close-up where the camera will not see it in the wide shot. An advantage of using LEDs in a ring light is that the fixture is quite lightweight, less bulky and to runs cooler than ring lights that use multiple tungsten bulbs. The amount of light provided by a ring light is critical to realistic lighting of a face. Too much fill light from the fixture can make the face look ghoulish or unrealistic; too little light leaves shadows too dark. Since the distance from the light to the subject will vary as the camera comes closer or moves further away, it is very helpful if the ring light is easily dimmable to compensate.

Litepanels, Gekko, LEDStorm, and others sell different versions of LED ring lights having a variety of features and sizes to fit various cameras. By using one of a variety of different brackets the ring lights can be fitted onto any camera or supported on a C-stand.

LEDStorm incorporates white, red, blue, green, and yellow LEDs into their ring light. The fixture comes with a control box from which each color can be separately controlled. The control box coordinates the blend of colors, which allows the light to be dimmed without a noticeable color shift. According to the manufacturer, by blending the various LEDs the light can be set to any color temperature between 6800 and 2800 K, or to any of the primary colors. The control box also offers preset effects such as fire, candlelight, television, police flashers, water, strobe and chase. The effect of modern police flashers, for example, is very effective.

Color wash fixtures

RGB LED fixtures

For scenes requiring colored light, RGB LEDs are advantageous because a single fixture can mix a multitude of different colors. In addition RGB LEDs produce intensity at the blue and of the spectrum in equal measure to the warm end, while tungsten lights are naturally biased toward the warmer colors because the transmission through saturated blue gels is very low. While these attributes offer real advantages, it is a mistake to think of them as a total replacement for gelled lights. Manufacturers sometimes like to say that more than 16 million colors are achievable with three channels of color. This sounds impressive, but this figure is simply the number of different possible combinations achievable from three DMX channels (each DMX channel has 256 possible values. $256^3 = 16.7$ million). As explained earlier, even RGBW LEDs cannot produce a great many of the colors one can get from gels and the look of RGB color mixing can be quite different than that of gelled incandescent lights.

Martin, Elation Professional and many others make a wide variety of theatrical color wash and strip light RGB LED units. Color Kinetics (Philips) makes a number RGB fixtures (originally for architectural lighting) notably the Color Blast, Color Blaze, and Color Reach (Figure 10.10).

City Theatrical sells many accessories for the Color Blast. These include polycarbonate and glass spreader lenses, wireless DMX512 power supplies, barn doors, top hat snoots, egg crate louvers, and

FIGURE 10.10

(A) The Color Blast RGB fixture measures 6-in. × 13.5-in. The head has 10° beam angle and can be fitted with a 23° frosted "lens" to broaden the beam, as well as horizontal and vertical spread lens. The Color Blast is used for small scale color washing or cyc lighting. The Color Blaze (B) is a large 4- or 6-ft RGB strip light. The Color Reach (C) is a large 21-in. 29-in. fixture with very bright LEDs designed to light large architectural facades. Both the Color Blast and the Reach can be fitted with a wide variety of spreader lenses. Depending on the lens installed, the fixtures can provide a wide wash light, or a longer throw spotlight.

(Courtesy Philips Color Kinetics.)

more. The fixture can be mounted using a pipe clamp bolted to the industrial hinge the light comes with. For our purposes the hinge can be retrofitted with a 5/8-in. (baby) spigot (available from City Theatrical). The clear and frosted glass lenses can be exchanged but this requires the removal of an "elastomeric sleeve" that protects the fixture from nicks, and two screws to hinge open the bezel. For our purposes the rubber bumper and screws are generally discarded so that accessories can be installed without the need of a screwdriver.

Power and control of Color Blast fixtures is a proprietary system similar in operation to power-DMX. A Power/Data supply powers a number or Blast fixtures, providing each fixture with 24 V DC power and a control signal using 4-pin XLR extensions between the fixtures and the Power/Data supply. The Power/Data supply can be attached to pipe or truss, or sit on the floor. It has an internal DMX manager that routes the control signals from the control console to the individual Blast fixtures using a Color Kinetics data protocol. Only the power supply needs a DMX start address. Each fixture uses three DMX channels, numbered sequentially based on which of the Power/Data outputs the fixture is plugged into. The Power/Data supply can also run various preprogrammed effects continuously without a console.

Selador fixtures

ETC takes the idea of using RGB LED in strip lights and color washes and carries it to another level. They have created three different LED product lines, each optimized for different color capabilities, called Lustr, Palletta, and Vivid (Figure 10.11). All three product lines use a combination of seven different colored LED chips to accomplish a wide color gamut. The difference between these three product lines is entirely in the LEDs and optics they employ. The Selador products serve as a kind of case study of the important differences achievable by designing a fixture with different LED and optics combinations.

Lustr is optimized for white light, light tints and skin tones. Although Paletta and Vivid can also generate broad-spectrum whites, Lustr's output is optimized for this purpose. It can achieve any correlated color temperature from 800 to 20,000 K. CRI tops out at about 90 at 3200 K.

FIGURE 10.11

Seledor fixtures are available in four lengths: 11-in. (one segment), 21-in. (two segments), 42-in.—shown here—(four segments), and 63-in. (six segments). Each segment contains 40 LEDs. The fixtures are all approximately 7 in. tall, and 7 in. deep.

(Reproduced by permission of Electronic Theater Controls, Inc.)

Paletta is optimized for subtle color creation including pure pastels and saturated colors. Paletta is capable of fine color matching with conventional sources. The control console software enables gel color selection using Lee, Roscolux, Apollo, or GAM gel numbers.

Vivid uses higher power (3.5 W) LEDs for a longer throw. It is optimized for strong saturated colors and deep pastels.

All Selador lights use a 12° optic on the LEDs. The fixture provides slots to insert up to two secondary spreader lenses. The secondary lenses are available in eight different beam angles between 10° and 80°, in 10° increments. Secondary lenses can be combined to create other beam widths.

Each Selador fixture uses eight DMX channels per segment as shown below. Each 11-in. segment can be controlled on a separate DMX address, or all addressed the same. Each segment represents one unit if load on the DMX512 signal, so up to 31 segments can be daisy chained together on a single DMX512 link.

	Data Channel	Color	Value	Function
1	Fixture address	Red	0-255	Intensity 0-100%
2	Fixture address + 1	Red-orange	0-255	Intensity 0-100%
3	Fixture address + 2	Amber	0-255	Intensity 0-100%
4	Fixture address + 3	Green	0-255	Intensity 0-100%
5	Fixture address + 4	Cyan	0-255	Intensity 0-100%
6	Fixture address + 5	Blue	0-255	Intensity 0-100%
7	Fixture address + 6	Indigo	0-255	Intensity 0-100%
8	Fixture address + 7	Master intensity control	0-255	Intensity 0-100%

Color temperature and Color matching is achieved using software in the control console. Given the large number of color channels, the software has the potential to offer a very high level of control. Of course control consoles can create any kind of programmed effect, so dynamic color effects have unlimited potential, and because the Selador fixtures can be quite large, they offer the potential to make these effects on a large scale.

Unique theatrical and architectural LEDs

There are hundreds of incarnations of LED Architectural and Entertainment LED fixtures. The most common forms of these are strip lights, Parcan-like wash lights and panels. A quick Internet search will give you an idea of the number of other implementations of LEDs all kinds of purposes. Color Kinetics, Elation Professional, Martin and others make many different theatrical and venue effects lights.

- Moving-head RGB wash fixtures
- MR and PL type led lamps (120 and 12 V)
- Battery-pack operated RGB panel lights with 10-h battery life
- UV fixtures (black light)
- Underwater RGB light fixtures
- Very low profile white, or RGB light strips

- Small architecturally aesthetic mini panels for wall washes (RGB or white)
- Rope lights (RGB or white)

There are LED versions of Fresnel and par lights that use some combination of warm white and cool white LEDs. Komet makes a Parcan-like fixture using 12 white spot LEDs (6000 K) that puts out about as much light as a 1k wide flood Par (Figure 10.12). The fixture is weather proof, can be used underwater, and like others I've described can be used on a battery, a dimmer is built in to power supply, DMX512 controllable.

LiteRibbon, by LiteGear, is a unique and adaptable implementation of LED technology for which there is any number of applications (Figure 10.13). LiteRibbon is a flexible ribbon of LEDs with an adhesive back. They can be bent to curve with the surface they are mounted on—into a circle as small as a 1-in. radius. They can be hidden in the set, stuck to the ceiling of a car, used for display shelf lighting, tucked in a sofit, used as instrument lights at a control desk, or in a vehicle or aircraft.

They can be integrated into costumes or to light a face inside a full-helmet. They can also be used as decoration right in the shot, to outline architecture, soffits or set elements. LiteRibbon is available in warmwhite and coolwhite color temperatures and RGB. There are standard and high-output versions. There are waterproof versions in each color. There is the standard surface-mount type (120° beam angle), a silicone diffuser (80° beam angle), and a side-emitting type (light emits from the narrow edge of the ribbon). LiteRibbons can be run directly from any DC source 6-12 V DC. LiteGear supplies various power accessories for LiteRibbon including power supplies, battery adapters, two-fers, flicker-free dimmers, DMX512-controlled dimmers, and vehicle adaptors.

FIGURE 10.12

Komet Parcan has an underwater version, handy for lighting pools and fountains.

(Courtesy Acme Light and Grip, Komet.)

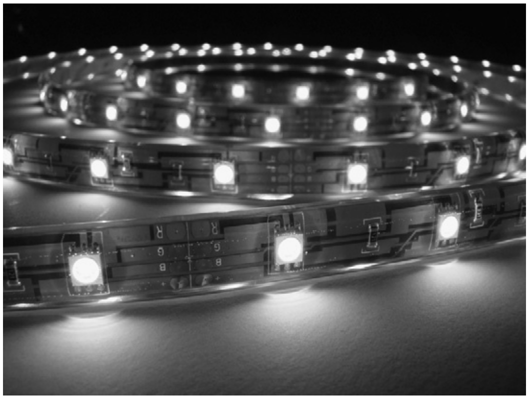


FIGURE 10.13

LiteRibbon can be made any length up to 16-ft. Every three LEDs there is a break point where the ribbon can be cut. A connector is then installed on one end and powered from a 6-12 V DC battery or power supply.

(Courtesy Al DeMayo, LiteGear, Inc.)

LED TECHNOLOGY

A typical LED fixture comprises four major component parts: an LED emitter, the fixture's heat sink, driver and dimming control, and augmenting optics. The emitter includes the die, a thermal heat sink, lens, and outer package (Figure 10.14). The *die* is the actual LED chip within the emitter. The color of the light is determined by the energy gap of this semiconductor. The thermal heat sink

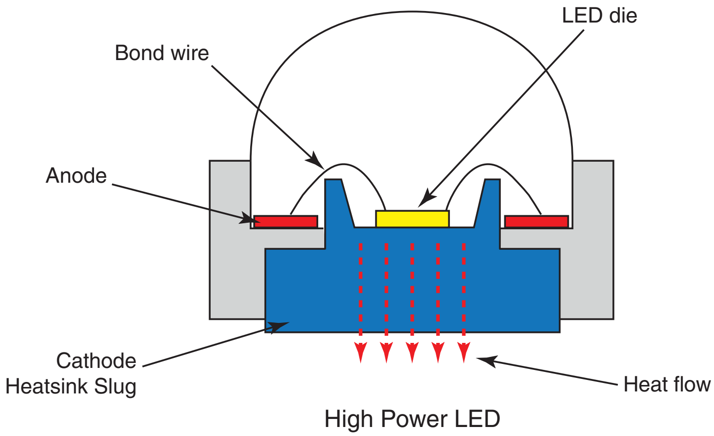


FIGURE 10.14

LED emitter. At its center is a diode chip, the die, capable of converting electricity to light energy very efficiently. Heat is dissipated into the thermal heat sink. A silicon lens covers this chip.

(Illustration courtesy Mike Wood.)

that is part of the emitter pulls the heat away from the chip and conducts it to the mass of the larger fixture (the fixture's heat sink).

The power supply electronics are designed to limit the *drive current* to the LED's specifications. In this regard LEDs are very sensitive; too much current can shorten their useful life from 50,000 h to nothing in an instant. This is why manufacturers warn that the light should not be used above a certain temperature. Controlling drive current is critical to the LED's brightness and useful life. An LED is a current-driven device, meaning that the intensity of the light generated depends on the amount of electric current flowing through it. Fixture designers try to design their lights with as high a drive current as possible, but there is a three-way relationship between brightness, lamp life and the ability of the fixture to dissipate the heat. LEDs are brighter at a higher current, but they loose efficiency if their operating temperature is allowed to rise. The balance a fixture designer can strike will also depend on the limitations posed by the spacing of emitters, the efficiency of the heat management. This is why almost all LED devices have large heat sinks and fins.

The lethal effect of overheating has prompted some manufacturers to provide safeguards against over-temperature situations by automatically increasing the speed of the cooling fan, and at some point, automatically reducing power or shutting off all together if the light approaches red-line, in order to draw the user's attention to the heat issue. This can usually be remedied by providing shade or better ventilation.

There are a couple different ways manufacturers can arrange the dimming. One way is to vary the drive current usually using pulse amplitude modulation (PAM). PAM is a method of current control that employs very high speed on/off switching to limit the current. By varying the timing of the switching the current can be lowered to dim the LED. A fixture dimmed using PAM will cut-out abruptly before it reaches full dim. The other way to dim LEDs is to use pulse width modulation (PWM) downstream of the driver. PWM modulates the intensity by varying the duty cycle at high frequency. This allows smooth dimming to nearly zero. For LED lights marketed for film and television, the frequency of the electronic power supplies, and PWM dimmer is typically greater than 20,000 Hz, and does not pose a risk of flicker at normal frame rates. Nila has actually done tests up to 7000 fps without capturing any flicker. However cheaper LEDs designed for the consumer market or club venues may use power supplies that cycle at 1 kHz or even lower, and these pose a definite risk of flicker, especially when the LED itself is being photographed at higher than normal frame rates. Testing is recommended.

The *optical components* of the LED, lenses and reflectors, extract light from the chip and shape the projection of that light in a focused beam. A total internal reflection (TIR) lens is a small molded lens used to capture light that is emitted in 180° from the die, and form it into a manageable beam of light. Advances in optics accounted for the lion's share of improvement in LED lumen output in the early years of their development. More recently improved chip technology and chemistry and better thermal management by the chip itself have contributed greatly to performance improvements.

As mentioned previously, some LED fixtures use interchangeable optics. A thin sheet of glass covers the chip to protect it. The optics should be kept clean, however do not use solvents or window cleaner as these can have adverse reactions with the assembly. Manufacturers recommend using a soft rag with isopropyl alcohol to clean the protective glass. Use water with mild soap for the optics.

Power factor

Power factor may be a concern when using very large numbers of LEDs. Color Kinetics and NILA fixtures are fully power factor corrected. Many of the devices described in this chapter may or may not have power factor correction. If they do not, you might expect to see a power factor of about 0.70. In a large installation this could create a significant nonlinear load (see Chapter 14). Check manufacturer's specifications.

LED useful life

LEDs very rarely just fail or suddenly burn out (unless seriously overheated). Normally they fade slowly over time, at a fairly consistent speed. Their useful life is defined in terms of *lumen maintenance*—the number of hours the emitter will operate on average before the lumen output decreases below a given percentage of initial light output. For example the emitter manufacturer will specify that an LED will produce at least 70% (denoted L70) of its initial output for 50,000 h, when driven at a particular current and a particular junction temperature. This is also sometimes stated as L75 or L50 (75% and 50% respectively). The L value that the manufacturer uses to produce their advertised lamp life figure makes a big difference. As a practical matter, a light that puts out less than 70% of its initial output would be considered pretty useless in our business.

Depending how the light designer configures the electronics and heat dissipation, and exactly which LEDs they choose the estimated lamp life can vary quite a bit. Manufacturers of lights used in our industry advertise lamp life from 20,000 to 100,000 hours. If you ran a 50,000-hour LED 8 hours a day, every day including weekends and holidays, the light would lose 10% of the initial output in about 6 years. At that rate, it would take a little over 17 years to reach 70% output. Of course once the LEDs are worn out, you just have to replace the whole fixture. Another factor that is easily overlooked in all this is that in theory the circuit components employed in the drive electronics have a shorter mean time to failure than the LEDs themselves, and may end up being the weakest link.

CHAPTER

11

Lighting control: Control networks, moving lights, advanced devices, and computer applications in lighting

As we have seen in the previous chapters, a broad range of lights and lighting devices can be controlled remotely on a control network. Typically, this is done from a central control console. In motion picture and television work, the most widely used control network protocol is DMX512. Every lighting technician needs to become familiar with it. However, DMX512 is just the beginning. With very large or complex rigs, Ethernet-based control systems are also commonly used. In this chapter, we will look at both.

As you may have noticed, the motion picture industry perpetually borrows technologies that have evolved in other areas of entertainment, photography, the arts, and industry. The art of theater lighting gave us: a bazillion gel colors, ellipsoidal spotlights, centralized dimming, and computer-based lighting control consoles. Rock-and-roll gave us: truss, portable power, dimming and data distribution, socopex cable, par cans, moving lights, and even more complex computer-based lighting consoles. In more recent years, the convergence of computer-based media manipulation with projector technology and moving light control has given us the ability to use moving image projections as lighting devices, running from a media server and controlled by an even more complex computer-based lighting console. A media server or console can also map pixels, graphics, or media files and display them as patterns on an LED wall or display, or map them into arrays of lights. It's great razzle-dazzle for a rock concert or trade show, but motion-picture lighting technicians have co-opted the technology to suit our own purposes. When we create lighting for alien spaceships, explosions, psychedelic mind trips, discos, helicopter spotlights, flickering fluorescent lamps, water effects, and so on, control consoles and advanced lighting/imaging devices can create unique dynamic effects that are highly adjustable, but at the same time consistent and repeatable.

Computer-based control technology goes hand in hand with computer-based previsualization technology. Borrowing visualization software developed for concert lighting, programmers render 3D models of the lighting on the computer with very good photorealism. This level of technological sophistication requires lighting technicians who are computer-savvy to run it. On big productions, tools like these are used to design the lighting and to anticipate problems before the rigging starts.

Other computer solutions like CAD-based light plots and lighting inventory programs give the lighting technicians effective communication tools for complex lighting and power distribution. Drafting these plots often falls to the lighting control programmer, because the programmer uses these plots to map the lights he or she is controlling. On a large-scale production, light plots are drafted that illustrate every part of the rig, from the power distribution, to the address assignments to the lights themselves. By the time tens of thousands of dollars of lighting equipment is on rental, and dozens of lighting technicians are on the payroll, they will have CAD drawings of the rig, with every trim height, truss dimension, and lighting position laid out.

Set Lighting Technician's Handbook, 4e. DOI: 10.1016/B978-0-240-81075-1.00011-8

The sophistication and complexity of control technology gave rise to a position on the lighting crew distinct from that of a dimmer board operator. Modern computer-based control consoles and control networks are run by a *lighting control programmer*, whose role can extend to include coordination of many technologies:

- Drawing CAD light plots
- Lighting sets in the virtual world using previsualization software
- Configuring Ethernet networks
- Planning and implementing wireless DMX systems
- Programming moving lights
- Preparing content and running media servers for lighting effects

In this chapter, we will start with the nuts and bolts of everyday control: the DMX512 control protocol, DMX512 devices, and control consoles. We will survey more advanced devices, including: moving lights, remote pan/tilt light-heads, media servers, projectors, and pixel mappers. We complete this chapter with the deployment of CAD design and lighting previsualization software. Each of these areas could be a book unto itself. There are several great books about automated lighting and lighting control that would be indispensable to anyone pursuing programming. The material presented here is meant as an introduction to these topics, and I hope it will provide an appreciation for the role of the programmer and the challenges that he or she faces. Whether you are a programmer, lighting technician, gaffer, or DP, it is helpful to understand the potential of these technologies, as well as where everyone else's job intersects with that of the programmer. We begin with the topic that any lighting technician needs to understand: DMX512.

DMX512

DMX512 (digital multiplex) is a type of communication network used to control dimmers and lighting devices. The current DMX512 standard is known as DMX512-A.[1] When it was first conceived, DMX was designed to replace the analog control of large numbers of dimmers.[2] Over the years, more and more devices have incorporated DMX512 control, as you have seen throughout this book: HMI ballasts, LED dimming fixtures, color-mixing LED fixtures, fluorescent fixtures, color scrollers, rotating gobos, irises, shutters, pan/tilt yokes and moving mirror attachments, distribution switching equipment, foggers, lightning effects, and of course moving lights. DMX512 is a fairly simple and reliable system if it is set up correctly; however, there are a number of ways things

[1]The Engineering Commission of the USITT, made up of representatives from various manufacturers, first created a DMX standard in 1986. It was revised in 1990, resulting in the USITT DMX512/1990 standard. Through efforts by the Entertainment Services and Technology Association (ESTA) beginning in 1998, it was further revised and eventually approved as an ANSI standard in 2004. The resulting standard, known as DMX512-A, is officially titled "Entertainment Technology—USITT DMX512-A—Asynchronous Serial Digital Data Transmission Standard for Controlling Lighting Equipment and Accessories."

[2]AMX192 is an analog multiplexed system that is capable of controlling up to 192 dimmers. You may occasionally come across venues that still use AMX192. Converter boxes are available to control an AMX dimmer from a DMX console and vice versa.

can go wrong that can lead to mayhem. In the sections that follow, we'll look at how a DMX512 system works, the proper way to set it up, and ways to test and troubleshoot problems.

The signal of a DMX512 network is generated by a *controller* such as a control console. The output from the controller, called a *data link*, provides data for up to 512 channels. Each device controlled by the signal is assigned to one or more channels. DMX512 uses *serial* data transmission, meaning that the data are distributed to devices by connecting each DMX512 device to the previous one in a *daisy chain* from device to device. The data speed is 250 kilobits/second, allowing a link to refresh the data for all 512 channels at least 44 times/second. The 512-channel link is known as a *DMX universe*.

The original DMX512 standard allowed data to move in only one direction, from the console to the devices. (We'll talk about provisions for two-way communications shortly.) DMX512 does not have error detection or correction. Because of this, it should not be considered for controlling pyrotechnics or laser lighting or any device from which there would be risk of harm to crew, performers or audience. Other control protocols are better suited for such situations. DMX512 should also not be used to control chain motors for moving truss or sets if this will cause the loss of manual control, as this poses a safety hazard.

DMX512 addressing

The lighting technician assigns each DMX512-controlled device a three-digit *start address* in the range from 001 to 512*;* this is the first channel number that the device will respond to. You will sometimes hear addresses referred to as *slots*. The term derives from the way the DMX512 communications protocol is structured. Each packet of data for the 512 channels begins with a "break" followed by a "mark after break" (MAB). This is followed by the "start code" and then data is transmitted in a fixed format: a start bit, followed by eight data bits and two end bits for each of the 512 channels. These framed data bytes are known as slots. Each receiving device starts counting slots after the start code, and when it reaches its assigned address, it responds to the data in that slot.

Each DMX512 device has an addressing interface, like one of those shown in Figure 11.1, where the start address is set. A device, such as a single stand-alone dimmer, occupies a single slot, and the start address is the only address to which it pays attention. For devices that utilize multiple slots, the start address is the first of several slots to which the device will respond. A dimmer pack with six dimmers responds to six slots of data, starting with the start address. If the start address is 001, then dimmers 1 through 6 will respond to slots 001 through 006. A DMX512 HMI ballast uses two channels: one for the dimmer level, and a second one to turn the light on and off. If the start address assignment for this ballast is 010, then the ballast will respond to slots 010 and 011.

You can assign multiple devices the same start address, and they will all respond to the fader values for that address. So if you have two identical devices that you always want to respond in exactly the same way, you *could* assign them the same start address. Typically, however, you will want to maintain as much individual control in the addressing as you can. Lights can be easily grouped and ungrouped using the console software, but changing an address on a light fixture that is way up in the rig can be a lot more trouble.

The flip side of this is that you do not want to accidentally address devices so that their channel numbers overlap. For example, if you assigned one HMI ballast start address 010 and the next HMI ballast start address 011, unexpected things would start happening. Reducing the value of fader 11 would dim the second light, but the first light would respond by shutting down.

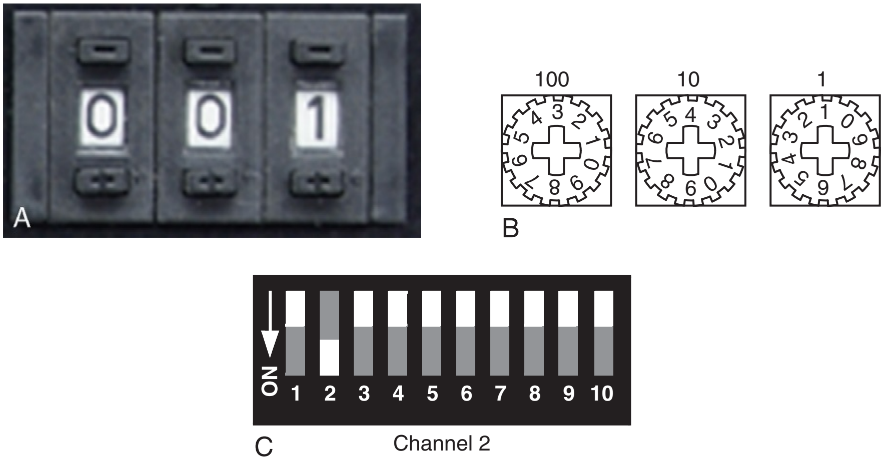


FIGURE 11.1

Three different DMX512 addressing interfaces: (A) wheel addressing is the most common and simplest; (B) a small Phillips head screw driver is used to set the address for an interface like this one. (C) binary addressing is often found on club venue effects lights like strobes. The easy way to translate binary code is to use simple software available online or an iPhone app. More information about binary code can be found on the *Set Lighting Technician's Handbook* Web site. Menu-based addressing (not shown here) is commonly found on digital dimmer racks, moving lights; and some HMI ballasts.

For most moderately sized sets, a universe of 512 slots leaves plenty of empty slots. When this is the case, the board operator may choose to address devices in a way that makes it easy to remember or figure out. For example, he or she might number the rig from bottom to top:

Up to 099	Ground row cyc lights
100s	Floor drops and practicals
300s	Lights hanging on the grid
300s	Backdrop sky pans
400s	Overhead space lights

This kind of numbering scheme leaves unused gaps in the DMX universe, groups of unused slots. This does not adversely affect the signal transmission in any way, and it leaves room for expansion.

Another example: if you are controlling two 96-dimmer racks, it is convenient for the dimmers numbers on the rack to correspond to the DMX address, so you could address them as follows:

	Address	Slots used
Dimmer Rack A	001	001-096
Dimmer Rack B	101	101-196

If the dimmer on channel 152 goes on the fritz, you know to look for a problem with dimmer module 52 on dimmer rack B. (If, on the other hand, you had addressed Rack B with the next available address, 097, then channel 52 would actually correspond to dimmer module 56, which is not as straightforward.)

A numbering scheme that originates in theater lighting allows the gaffer to easily deduce the channel for lights without need of a cheat sheet. Let's use a simple stage lighting scheme as an example. Say the stage is divided into five acting areas, and each of these areas is covered by one light from front left, one from front right, and one back light. The numbering scheme is as follows:

	Acting areas				
	1	**2**	**3**	**4**	**5**
Left Front Light	001	002	003	004	005
Right Front Light	011	012	013	014	015
Backlight	021	022	023	024	025

The Ones digit stands for the number of the acting area: 1-5

The Tens digit indicates the lighting position: 0 for stage left, 1 for stage right, and 2 for back light.

So if the gaffer wants to bring up the backlight for area 3, he or she knows to call for channel 23. Similarly, any grid of lights can use an intuitive numbering system like this. Say you have lights hung in eight rows of six columns and each light needs to be individually controlled. You could number the columns with the tens digit and the rows with the ones digit, as shown in the following table. If the light you want is the fifth one over from the left and the seventh one down, then you know the channel number is 057.

	1	**2**	**3**	**4**	**5**	**6**
1	011	021	031	041	051	061
2	012	022	032	042	052	062
3	013	023	033	043	053	063
4	014	024	034	044	054	064
5	015	025	035	045	055	065
6	016	026	036	046	056	066
7	017	027	037	047	057	067
8	018	028	038	048	058	068

These are just a couple examples of how you can use the numbering system to make sense with the placement of the lights. You could further expand this idea to include the hundreds digit. You can use odd numbers and even numbers for different functions (like warm gelled lights and cool gelled lights).

When a programmer is patching large numbers of multiple-attribute devices like moving lights, each light takes up a substantial block of slots. In this situation, the programmer will want make the most efficient use of the available addresses by leaving *no empty address slots* between devices. Conceivably, you might run out of slots if you leave gaps shorter than the slot footprint of the fixtures. The advanced consoles that are used to control moving lights are capable of creating the patch automatically, so in this scenario, the task of calculating the correct start address is automated. If there are 21 moving lights, and each one uses 24 slots, the start addresses would be:

Fixture	Address
Fixture 1:	001 (slots 1–24)
Fixture 2:	025 (slots 25–48)
Fixture 3:	049 (slots 49–72)
Fixture 4:	073 (slots 73–96)
. . .	
Fixture 21:	481 (slots 481–504)

Typically, the programmer will try to separate moving lights from conventional lights, either by allocating them their own block of numbers or by putting them on a separate universe altogether. If at all possible, the programmer will want to supervise the addressing of the light fixtures, according to his preferred method. This is especially true when there are multiple universes. A programmer may decide to use one universe strictly for dimmers, a second for moving lights, and a third one for the media server. Or, for example, he or she may decide to make the north side of the sound stage universe 1, the south side universe 2, and so on.

For a small rig, it is a simple matter for the riggers to work out fixture addresses before they hang the devices and lights. For larger productions, the programmer may want to prepare a light plot for the riggers that specifies the DMX addresses. The programmer may generate the addresses from the CAD software used to draft the light plot, or may already have loaded the lights into the control console and generated the addressing schedule from there, or might work it out in a spreadsheet program. Working out addressing on one of these computer platforms is a good idea, because it reduces the chance that something will be addressed improperly, and it allows the programmer to be further ahead of the game.

DMX values and device personality

When the control console communicates with the DMX512 devices, it sends an 8-bit *value*—a number from 0 to 255—to each address. The DMX512 device responds according to this value. A dimmer, for example, responds just as you would expect; you increase the fader value and dimmer increases intensity from 0% to 100%. For ease of use, control consoles typically display the values for dimmer channels as a percentage (0–100%), rather than the actual 8-bit DMX value (0–255). Many consoles support using either DMX values or percentages.

It is theoretically possible to have a light fixture perform up to 256 different tasks depending on the DMX value sent from the console. The response to the DMX value depends on how the device is

designed to function. The way each device uses a DMX value to cue a particular response and the mapping of DMX channels to the functions of the fixture is known as the *DMX protocol* for that device, or its *personality*. A programmer must study the DMX protocol of each device connected to the console to be familiar with all its attributes. The personalities of light fixtures are listed in the unit's User Manual and are available for download from manufacturer's Web sites. Let's look at some examples.

A six-dimmer pack has a very simple device protocol (Table 11.1). The pack requires six channels, each controlling the level of a dimmer circuit from 0% to 100% output.

The HMI ballast (Table 11.2) dims to 50% output using the first channel, but notice that the protocol is set up so that below 128 (50%), the fader no longer changes the response, because HMI's don't dim below 50%. The ON/OFF function is on a separate channel, which operates like a two-position switch (1–50% = off, 51–100% = on).

The Image 85 fluorescent fixture is an example of a fixture with a fairly complex DMX protocol. First of all, it has two different modes, INDIVIDUAL and FIXTURE. When the Image 85 fixture is placed in FIXTURE mode (Table 11.3A), the entire fixture can be controlled with only two DMX channels (which, in the case of the Image 85 fixture, are first and *ninth* channels). The first channel increases the number of lamps that are ON from 0 to all 8 as the DMX value rises from 0 to 255. (The order in which the lamps turn on is preset by the fixture manufacturer and cannot be controlled.) The ninth channel works like a two-position switch, LO output up to 50%, and HI output above 50%. When the Image 85 is placed in INDIVIDUAL mode (Table 11.3B), a separate channel controls each lamp; an eight-lamp fixture uses nine channels, and each operates like a two-position switch: OFF/ON. The ninth channel controls the HO/STD mode. It is not uncommon for complex lights to provide more than one operating mode so that the user can assign

Table 11.1 Dimmer pack with six dimmers (six channels)

Channel	DMX value	Function
1st	0–255	Dimmer 1 intensity 0–100%
2nd	0–255	Dimmer 2 intensity 0–100%
3rd	0–255	Dimmer 3 intensity 0–100%
4th	0–255	Dimmer 4 intensity 0–100%
5th	0–255	Dimmer 5 intensity 0–100%
6th	0–255	Dimmer 6 intensity 0–100%

Table 11.2 DMX512 HMI ballast—ARRI (two channels)

Channel	DMX value	Response
1st	1–127	Remains dimmed at 50%
	128–255	Dim level from 50% to 100%
2nd	0–127	Fixture shut OFF
	128–255	Fixture turned ON

Table 11.3A Image 85—Kino Flo (in FIXTURE mode, two channels)

Channel	DMX value	Response
1st	0	All lamps OFF
	1–31	1 lamp ON
	32–63	2 lamps ON
	64–95	3 lamps ON
	96–127	4 lamps ON
	128–159	5 lamps ON
	160–191	6 lamps ON
	192–223	7 lamps ON
	224–255	8 lamps ON
9th	0–127	Fixture on LO OUTPUT setting
	128–255	Fixture on HI OUTPUT setting

Note: In FIXTURE mode, an Image 85 does not use the 2nd-8th channels. This is an uncommon arrangement for a DMX512 protocol.

Table 11.3B Image 85—Kino Flo (in IND mode, nine channels)

Channel	DMX value	Response
1st	0–127	Lamp 1 OFF
	128–255	Lamp 1 ON
2nd	0–127	Lamp 2 OFF
	128–255	Lamp 2 ON
3rd	0–127	Lamp 3 OFF
	128–255	Lamp 3 ON
4th	0–127	Lamp 4 OFF
	128–255	Lamp 4 ON
5th	0–127	Lamp 5 OFF
	128–255	Lamp 5 ON
6th	0–127	Lamp 6 OFF
	128–255	Lamp 6 ON
7th	0–127	Lamp 7 OFF
	128–255	Lamp 7 ON
8th	0–127	Lamp 8 OFF
	128–255	Lamp 8 ON
9th	0–127	Fixture on LO OUTPUT setting
	128–255	Fixture on HI OUTPUT setting

Table 11.4 MaxMover remote head—ARRI (employing ARRI FP DMX interface)

Channel	DMX value	Response
1st	0–255	Pan coarse (50% = center “home” position)
2nd	0–255	Pan fine
3rd	0–255	Pan speed
4th	0–255	Tilt coarse (50% = center “home” position)
5th	0–255	Tilt fine
6th	0–255	Tilt speed
7th	0–255	Focus flood to spot
8th	0–101	Lock
	102–153	Release
	231–255	Home position

the MODE according his or her own priorities. If the application is pretty routine, and the programmer wishes to conserve channels, the user assigns a simpler mode; if a higher degree of control is required for a particular application, then he or she sets the MODE to the higher level of functionality, requiring more channels.

The ARRI MaxMover remote head can be controlled by either a simple three channel DMX converter, or by an eight-channel fully programmable (FP) DMX converter (protocol shown in Table 11.4). In FP mode the pan and tilt parameters are each controlled by two channels: coarse and fine. Fixtures use two channels for a single attribute to increase *resolution*. By going from 8-bit (one channel) to 16-bit (two channels), the resolution of pan and tilt increases from 256 possible positions to 65,536 possible positions. This smoothes out slow pan/tilt movements and increases the accuracy with which the light can be focused. Note that the eighth channel of the Max Mover operates like a three-position switch between LOCK, RELEASE (for normal operation), and HOME.

Selador LED color wash fixtures use seven channels for additive color mixing (Table 11.5), and the eighth to dim the fixture overall while maintaining a particular color. Of course a programer does not normally want to be mixing colors by hand using seven faders. An advanced control console

Table 11.5 Selador LED fixture—ETC (eight channels)

Channel	DMX value	Function
1st	0–255	Red intensity 0–100%
2nd	0–255	Red–orange intensity 0–100%
3rd	0–255	Amber intensity 0–100%
4th	0–255	Green intensity 0–100%
5th	0–255	Cyan intensity 0–100%
6th	0–255	Blue intensity 0–100%
7th	0–255	Indigo intensity 0–100%
8th	0–255	Master intensity 0–100%

provides ways that the programmer can pick the color from a color picker displayed on a touch screen, or from a look-up table indexed by gel color.

The protocol for moving light fixtures can be very complex. Table 11.6 gives an example of a light that has three different modes and over thirty attributes. Many of these attributes are controlled in a linear fashion (colors, dimmer, iris, and so on); others are not. For example, channel 6 operates the stop/strobe

Table 11.6 Clay paky alpha 1200 control protocol

Channel	Mode setting		
	Standard	**16 bit**	**Extended**
1	Cyan	Cyan	Cyan
2	Magenta	Magenta	Magenta
3	Yellow	Yellow	Yellow
4	Linear CTO	Linear CTO	Linear CTO
5	Color wheel	Color wheel	Color wheel
6	Stop/strobe	Stop/strobe	Stop/strobe
7	Dimmer	Dimmer	Dimmer
8	Iris	Iris	Iris
9	Fixed gobo	Fixed gobo	Fixed gobo
10	Rotating gobo change	Rotating gobo change	Rotating gobo change
11	Gobo rotation	Gobo rotation	Gobo rotation
12	Blade 1A	Blade 1A	Gobo fine
13	Blade 2A	Blade 2A	Blade 1A
14	Blade 1B	Blade 1B	Blade 2A
15	Blade 2B	Blade 2B	Blade 1B
16	Blade 1C	Blade 1C	Blade 2B
17	Blade 2C	Blade 2C	Blade 1C
18	Blade 1D	Blade 1D	Blade 2C
19	Blade 2D	Blade 2D	Blade 1D
20	Framing rotation	Framing rotation	Blade 2D
21	Prism/animation effect/frost	Prism/animation effect/frost	Framing rotation
22	Prism/animation effect rotation	Prism/animation effect rotation	Prism/animation effect/frost
23	Focus	Focus	Prism/animation effect rotation
24	Zoom	Zoom	Focus
25	Pan	Pan	Zoom
26	Tilt	Tilt	Pan
27	Reset	Reset	Pan fine
28	Lamp on/off	Lamp on/off	Tilt
29		Pan fine	Tilt fine
30		Tilt fine	Reset
31		Gobo fine	Lamp on/off

functions. A range of DMX values is assigned to activate each effect or macro such as shutter open, shutter closed, random strobe (different assignments for different speeds), pulsation (different assignments for different speeds), and strobe at different speeds. To access the features of each light, the programmer must be familiar with these features and must know how to harness the power of a computer-based control console.

Controllers

In its most basic form, a DMX controller is a device that generates a DMX512 signal based on inputs from the user. DMX controllers come in many levels of sophistication. A *dimmer board* is a simple controller that typically uses slider faders to control levels and has some memory capability. A *control console* is a computer-based controller with a complex interface designed to give a proficient programmer a wide spectrum of control features. Today's top consoles are capable of controlling thousands of devices, multiple universes, and complex devices such as moving lights and media servers (Figure 11.2).

Most companies that make control consoles also offer PC console emulation software or an off-line editor, which can be used offsite to work on the programming for a show (and also to learn and explore the features of the software) however emulation software typically prohibits the use of the PC as a console itself. However, a number of companies have developed their own control software to use a PC as a lighting console (Figure 11.3A), connected with the DMX512 network using a USB PC DMX interface. When control is relatively simple, such as on a television series, a laptop and PC DMX interface may be all that is needed to run the show. Although the PC software can typically do almost everything the console can do, it lacks the multiple screens and specialized keyboard functions for complex programming tasks. Users can add wings and additional monitors to their computer for programming and playback functions, providing a faster and easier interface.

FIGURE 11.2

Programmer John Crimins controls an immense set for the movie *Iron Man 2*. The rig includes: C-Splash fixtures in pools (Color Kinetics submersible color LEDs), LiteRibbon RGB LEDs around the lip of the pools, PRG Bad Boy moving lights on towers, conventional lights on dimmer circuits, and fluorescents lighting an immense green screen. Versa TUBE LED tubes are mounted to the columns in the distance. When active they displayed a waving American flag via a Catalyst media server. The console is a Hog III console by High End Systems.

(Courtesy Mike Bauman.)

FIGURE 11.3

(A) This laptop computer runs LSC Clarity. It is connected to the DMX512 network via a wireless DMX PC interface (not shown). The righthand monitor shows the program and the lefthand monitor shows the real-time rendering. The faders on the left are the playback wing, which is an optional add-on. There's also a programming wing available. (Photo courtesy Richard Cadena.) (B) The Pocket Console has eight faders but controls an entire universe. It is also available in a wireless version. (Courtesy Baxter Controls, Inc.) (C) The Apathy can select and control any channel using a single knob. (Courtesy Doug Fleenor Design, Inc.)

The full operation of control consoles is beyond the scope of this book, but the basic functions of a lighting console include:

- Levels—Sets levels for lights and DMX512 devices.
- Presets—Stores in memory the levels for all the lights.
- Cues—Executes cues using timed fades and cross-fades to transition between presets. The console can also link cues and make presets dim or crossfade at different speeds or insert a delay before beginning a fade.
- Cue list—Keeps cues in a list for sequential playback. This is how light cues are executed for a theatrical performance, or for individual songs in a concert.
- Group—Allows the programmer to group lights in multiple ways for ease of control.
- Patch—Provides a means for the programmer to number the lights any way he or she wishes (fixture numbers), and frees the programmer from having to deal with the actual DMX addresses.
- Submasters—Assigns groups of fixtures or a sequence of cues to a fader.
- Palettes—Stores a set of values for color, position, beam, or intensity in a lookup table that can be applied to a compatible light or group of lights and recorded in a cue with a single button-push. This is very handy for moving lights, but is also useful for any device with more than one attribute. A palette is created and customized by the programmer. Changing a palette changes every occurrence of that palette in every cue in the show, making it easy to make global changes to a show without having to do it one cue at a time.
- Effects—Consoles provide tools for creating effects sequences—a series of complex light cues that can be played back. The simplest example would be flash or chase effects, but effects can be manipulated in many ways to create patterned and random effects such as lightning, flame, and so forth.
- Playbacks—A moving light console utilizes multiple playbacks, that is, cue lists assigned to a fader used for running a particular routine on selected lights.
- Showfiles—All work is saved as a show file, which can be copied, backed up, archived, removed, and taken home, edited on emulation software away from the job site, emailed, and shared with others.
- Remote Cueing—Another way to trigger a light cue is to connect a remote switch to the control console, which executes the lighting cue. This momentary switch could be installed in a handheld switch-box activated by a lighting technician on the set, or it could be installed into the set as a wall switch and activated by the actor.

Moving light consoles

A key philosophy of a moving light console's operating system is that the programmer should not have to be concerned with the specific operational characteristics of each of the different lights when he is programming looks and movement. The programmer thinks in terms of aesthetic parameters common to all the lights, such as color, position, beam and intensity, and these are what the programmer controls with the console. The Whole Hog 3 User Manual refers to this as the "Abstract Layer" because the software acts as an additional layer between the user and the lighting hardware. The console can do this because it maintains a working library containing fixture profiles for all of the different lights. It can therefore interpret the programmers aesthetic inputs into DMX values appropriate the individual make, model and software version of each fixture. With just a few keystrokes, a programmer can instruct the console to take fixtures 1 through 6, focus them down stage center, make them all Congo blue, and spin a particular gobo in a prescribed way. The programmer can do all this without ever having to consider DMX addressing or values, fixture profiles, color mixing, or any of the multitude of parameters required to execute that instruction.

Another important function on moving light consoles is *fixture numbers*. This allows any group of channels to be programmed as a fixture. In other words, no matter how many slots the light uses, the console represents it as one unit, and the lights can therefore be numbered sequentially regardless of their slot footprint. Say you have a bunch of space lights, and you wish to turn on three of the six circuits on all of them. This can be accomplished with a single command sequence if the console is set up to identify each group of six channels as one fixture. No longer does the programmer have to look up the channel numbers for each of those circuits; the console takes over that task.

TERMS FOR DIMMER SYSTEM AND CONTROL

Circuit	The electrical supply downstream of the dimmer, from the dimmer's output connector to the lighting fixtures themselves. All cables serving a circuit should be labeled at both ends with the circuit number.
Dimmer	The device controlling the power level to a circuit and lighting fixtures. Two lights on one dimmer circuit cannot be controlled separately. Dimmer numbers may or may not correspond to circuit numbers, depending on the hardpatch (see "hardpatch").
Hardpatch	The physical plugging of circuits to dimmers using a patch panel (sometimes called a *spaghetti patch*). ETC Sensor dimmer racks provide a patch panel within the rack.
DMX512 Device	Any device incorporating a DMX512 receiver and connected to a DMX512 network—dimmer, HMI ballast, LED, fluorescent fixture, fogger, DMX512 distribution box, etc.
Slot	The positions within a DMX packet. Slot numbers go from 1 to 512.
Start Address	The three-digit address (001-512) entered on the fixture, which represents the first channel that the device will respond to.
Channel	The console's control circuit for a device or group of devices. In a simple system, there is a fader for each channel. On most current control systems, channels are numbers, accessed by a numeric keypad. In a DMX512 network with only one universe, the channel may correspond to the DMX address, but DMX512 networks with multiple universes can number the channels sequentially (beyond 512).
Soft-Patch	The electronic assignment of dimmers to channels in a console made by the console operator. Multiple dimmers can be soft-patched to a single channel, but a single dimmer cannot be patched to multiple console channels. It is incorrect to use the term "patch" to refer to the assignment of channels to cues or submasters.
Fixture Number	The unique name or number assigned to a DMX512 device on the control console by the console operator. Fixture numbers provide a way to reference all fixtures and devices sequentially, or in any way the programmer prefers, without respect to channel or address. Each fixture can be labeled with its fixture number (once assigned), for ease of communication between set electricians and programmer during lighting.
Preset	A predefined set of intensities or values for a set of channels, stored in memory for later replay.
Memory	The storage location for preset information.
Cue	The process of recalling a preset from its memory location and putting the result on stage.
Submaster	A controller (usually a linear fader) that allows for manual control of groups, effects, cues, or channels.
Fade	A gradual change in stage levels from one set of intensities or values ("look") to another.
Up-Fade or Fade In	The portion of a fade that involves only channels that are increasing in level.
Down-Fade or Fade Out	The portion of a fade that involves only channels that are decreasing in level.
Cross-Fade	A fade that contains both an up-fade and down-fade. This also may refer to any fade in which the levels of one cue are replaced by the levels of another cue.
Bump	An instantaneous change in stage levels from one set of intensities or values ("look") to another.

Small controllers

A variety of very small handheld controllers like those shown in Figure 11.3B and C are commonly used to control DMX512 devices directly on set (e.g., for a light cue) and for testing equipment and for system trouble-shooting. Although these devices possess only a few buttons, they generate an entire universe of 512 channels and can even be programmed to display presets.

Multiple DMX512 universes

Most modern consoles support multiple universes and may come configured with two, three, four, or more DMX512 data links. In addition, many modern consoles use Ethernet networks to expand the system and add even more universes. DMX512 networks with 15 or 20 universes are not unheard-of on big-feature productions. Figure 11.4 offers three increasingly complex examples of DMX topology.

Each universe has its own separate data link. The slots of each universe are numbered from 1 to 512, so the 513th device would be assigned to slot 001 of the second universe.

The syntax on consoles for universes and slots is commonly written like this:

1/512 or **1:512** (where 1 is the universe and 512 is the slot)

When rigging, circuits will often be labeled with the universes lettered:

A 512 (where A is the universe and 512 is the slot number).

In big systems, there may also be separate nodes, for which the syntax is:

1:2:512 (where 1 is the node, 2 is the universe and 512 is the slot)

Fixtures in different universes will have the same DMX512 address assignments, but different absolute addresses:

	DMX address	Absolute address
Universe 1	1/001-1/512	001-512
Universe 2	2/001-2/512	513-1024
Universe 3	3/001-3/512	1025-1536
Universe 4	4/001-4/512	1537-2048

There are iPhone applications and computer widgets available that translate any universe/DMX address into an absolute address or vice versa. When you number your dimmers, no two dimmers should have the same number; once you go beyond 512 dimmers, the dimmer and circuit labels should include the universe or the absolute address as described above. You can see how critical it becomes to label every piece of DMX512 equipment (dimmer racks, opto-splitters, dimmer circuit cables) with all relevant information. An electrician needs to be able to plug into a free dimmer circuit and ask for it to be brought up on the console. To do this, the connector must be labeled with a unique number.

Running DMX512 cable

There are specific standards and procedures for running DMX512 cable that help assure a reliable signal. The basic rules are summarized in the sidebar (“Rules for Running DMX512 Cable”). This section will flush out more of the details.

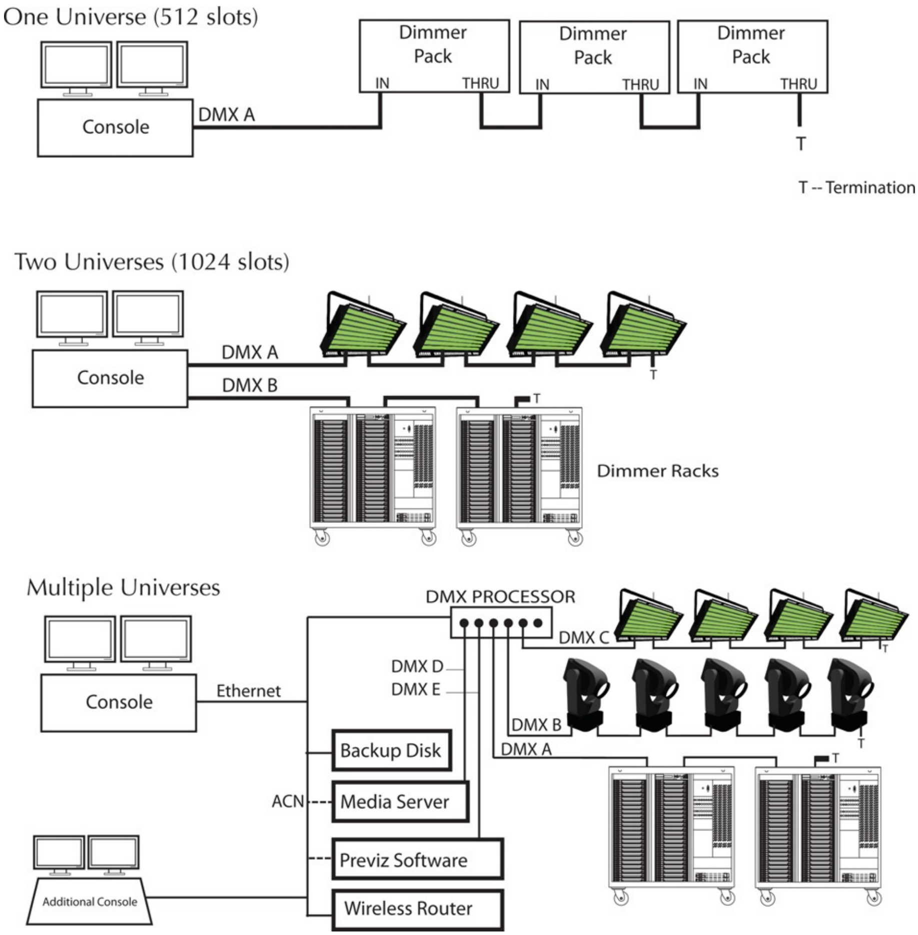


FIGURE 11.4

A network may be as simple as a single DMX universe (top), or expanded to include two, three or four universes by employing a console configured with multiple data links (center). The network can be expanded almost infinitely using an Ethernet-based network protocal (bottom).

As you probably know, data communication is in binary code – a series of zeros and ones organized into meaningful blocks by conforming to a prescribed protocol (in this case DMX512-A). Ones and zeros are transmitted as voltage and no voltage. On a data cable connector the pins 2 and 3 are the ones responsible for communicating data. Pin 3 is called true data (sometimes noted 1+). Pin 2 is called the data complement (1−). The control console generates a signal that is fed into the data link by a line driver (an operational amplifier, or op-amp).

A differential line drivers delivers an amplified data signal by creating a voltage differential between the two wires. When the true data line outputs a positive voltage, the complement outputs a

negative voltage, and when the true data line outputs 0 V, then the complement does, too. The differential voltage is small—about 10 V. The receiver interprets 0 V as a binary 0 and 10 V as a binary 1. In this way, the driver is able to transmit binary code to the receivers in the DMX512 devices.

RULES FOR RUNNING DMX512 CABLE

- When you initially run the DMX cable, run *two lines* so that you always have a spare cable already in place. The cost of renting extra cables is nothing compared the cost of delay during production.
- Provide termination after the last fixture at the end of each run of DMX512 cable, using a terminator plug or termination switch on the last DMX512 lighting device. (Be sure that any device equipped with a termination switch does *not* terminate *unless* it is the last DMX512 device on that link.)
- A DMX512 signal is supposed to be strong enough to feed up to 32 DMX512 devices. To feed additional devices, the signal must be regenerated using a device such as an opto-splitter or DMX512 amplifier. An opto-splitter is itself a DMX512 device, so you can have as many as 31 DMX512 devices, and then an opto-splitter. In reality, 32 devices is a lot to put on one DMX512 link transmitter. Experience has shown that regeneration after no more than 16 devices assures better reliability.
- Never directly connect DMX512 cable between two devices that are powered from two separately derived power sources that are not bonded, such as building power and a generator. An optical isolator must be used between any two such devices.
- Never use a hard-wired Y-splitter on a data cable.
- A DMX512 signal is typically strong enough to feed a total cable length of 1000 ft. If a longer distance is required the signal must be amplified using a device such as an opto-splitter. Here again, actual mileage may vary. Many programmers feel far more comfortable with cable lengths of no more than 500 ft. It depends to a large extent on the number of devices connected in the cable run. Each connection point sinks current.
- The cable used must meet the design criteria for high-speed data cable: 100-120 Ω, low capacitance, no smaller than 24 AWG wire in twisted pairs.
- DMX512 cable and XLR connectors should be treated with the utmost care. One crushed connector can bring a whole production to a grinding halt, and no one will even know where to start looking for the problem. Test control cable using a DMX tester (not a DC continuity checker like a microphone cable tester).
- DMX512 cable should be rigged high near the ceiling, away from power cables, out from under foot, and out of harm's way.
- The XLR connectors are a point of potential failure and must be protected from strain. Tie a strain relief at connection points so that the cable takes any pull, not the connector. Do not tie the cable in a knot to do this (this bends and strains the cable where it exits the connector). Make a big loop and use the cable tie-strings to make the strain relief.

The pin configuration for DMX512 cable is shown in Figure 11.5. Pin 1 is common. It is a 0-V reference for pins 2 and 3, which are minus and plus voltages, respectively. People sometimes confuse common with ground; they are not the same. Pin 1 should not be connected to the shell. Pins 2 and 3 are the active data conductors. Pins 4 and 5 were originally designated for future expansion of DMX512 capability or to include a second universe on a single cable, but because some manufacturers started using these free pins for other purposes, future expansion now creates conflicts, and pins 4 and 5 are commonly unused.

The DMX512-A standard specifies the use of 5-pin XLR connectors. However, you will find equipment that deviates from this standard. For example, some moving lights use a 3-pin XLR (arrange as shown in Figure 11.5B). A simple 3-to-5-pin adapter cable allows 3-pin devices to be plugged into a 5-wire system. Another deviation from the 5-pin standard is a 4-pin XLR system commonly known as *Power/DMX*, used for devices like color scrollers and gobo rotators (described in Chapter 3).

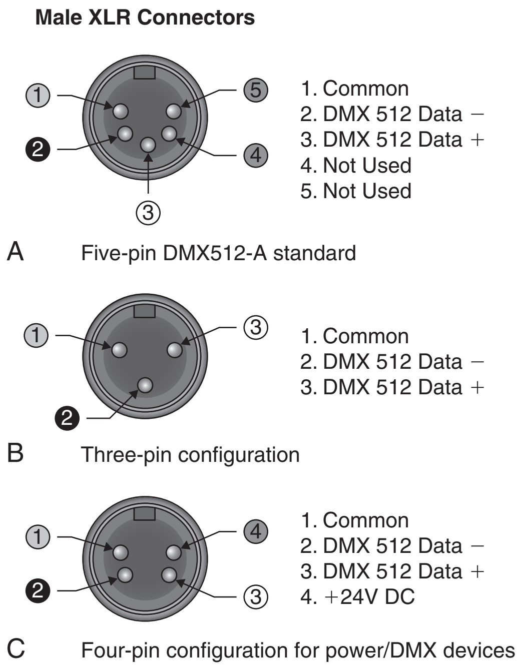


FIGURE 11.5

DMX512 pin-out diagrams of a male XLR connector: (A) 5-pin DMX512-A standard, (B) 3-pin DMX, (C) 4-pin Power/DMX.

The fourth pin provides 24VDC power to the device (Figure 11.5C). A Power/DMX power supply connects to the DMX512 signal via the standard 5-pin XLR input. It then combines the control signal with the 24VDC power into one 4-wire cable, which can commonly feed several of these small devices. Because this creates the potential for power to be inadvertently applied to the communication wires by a shorted wire or improperly wired connector, Power/DMX supplies should be optically isolated as a precaution to protect all the DMX512 devices upstream from potential damage.

The data link is a female 5-pin XLR connector. Each DMX512 device has a male DMX IN and female DMX OUT (or THRU). All of the devices in a DMX512 universe are daisy-chained together; each DMX512 device gets the control signal fed to it through the previous DMX512 device.

The DMX OUT of the last device in the chain is fitted with a *terminator*. The terminator is just an XLR plug that has a 120-Ω, 0.25 W resister connected between pins 2 and 3. Many modern devices provide a termination switch that can be used to terminate the signal at the last device (however, some practitioners believe that a terminator plug is more reliable). Termination absorbs the signal at the end of the data line by matching the impedance of the cable (as if the cable just keeps going to infinity). Without a terminator, the signal runs up against infinite impedance at the end of the line, which is like a rubber ball hitting a concrete wall. It reflects the signal back up the line toward the source. Reflections corrupt the data because of phase cancellation. Improper termination often goes undetected on smaller installations, because devices will sometimes still function. However, without proper termination, the signal along the entire line is compromised. When there are many devices on

the network or longer lengths of cable, some devices will start acting erratically or not responding. Things can appear just fine and then suddenly stop working. Moving lights sometimes develop a twitch.

A DMX512 signal is strong enough to feed 32 "units of load"—which means 32 DMX512 devices. In practice, technicians commonly limit the load to 16 devices. Each device, and the cable between them, sinks current from the transmitter, especially when the cable lengths are very long. At some point, the signal becomes too weak to be reliable. It is good practice not to use cables that are much longer than needed and to not string together multiple cables that are shorter than needed. Each connection point increases resistance and risk of failure; the fewer, the better.

There is also a limit to the total length of the DMX512 cable from the console. The maximum specified in the RS-485 standard is up to 1 km (3281 ft.). However, in practice, the limit is much shorter. Some manufacturers say to use no more than 1000 ft. Some recommend keeping it below 500 m (1640 ft.). Many programmers I've talked to prefer to be even more cautious, and do not exceed 500 ft. without regenerating the signal. To regenerate the signal, an optical splitter (covered shortly) or data repeater is installed inline.

The cable used for wiring DMX512 must be appropriate for high-speed data transmission. It must meet certain standards: 24 AWG wires in twisted pairs, 100-120 Ω impedance, low capacitance, and a foil shield and overall braided shield. The data line uses twisted-pair cable to help cancel out electromagnetic noise if it is picked up on the line. Because it is picked up equally by both the wires it cancels at the differential amplifier. RS-485 cable is 120 Ω cable; RS-422 cable is 100 Ω cable. Both kinds are used in the field, but it is best to use either one or the other for the entire rig, because in long runs, a change of impedance between cables can cause reflection issues. These precautions help reduce noise and interference, line loss, and signal degradation.

Just because a cable has an XLR connector does not mean that it is a good cable for DMX512. In fact, audio cables—which use 3-pin XLR connectors—are completely wrong for digital signals. Microphone cable has high capacitance and relatively low impedance. The capacitance of the cable actually alters the shape of the waveform. A clean data signal looks like a square wave with sharply delimited changes in voltage differential. On long cable runs, a high capacitance cable has a tendency to alter the shape of the waveform to a sawtooth shape, which DMX512 devices will have trouble reading.

CAT5 cable, which is commonly used for computer networking and for telecommunications, has also been tested and approved by ESTA for use with DMX512-A in permanent installations; however, CAT5 cable is far less rugged than DMX512 cable, and is typically avoided for hard use. Because CAT5 cable is available in very long spools, it can be very convenient for wiring long home runs, and because it is very inexpensive, it can be thrown away once the show is completed. For a long-running show, a television series or large feature film, this could be worthwhile. The RJ-45 connector on CAT5 cable is wired as follows:

Pin 1	Data 1+
Pin 2	Data 1−
Pin 3	Data 2+
Pin 4	N/A
Pin 5	N/A
Pin 6	Data 2−
Pin 7	Common (0 V) for Data 1
Pin 8	Common (0 V) for Data 2

Optical isolators and splitters

Opto-splitters and opto-isolators are devices that read the incoming DMX512 signal, transfer it optically within the device, and then regenerate the signal for output. An optical *isolator* is a device that has one DMX512 input and one output. An optical *splitter* is an opto-isolator that has one input, but incorporates multiple optical receivers to regenerate identical data signals for multiple separate outputs.

There are several benefits to this technology. First, because there is no electrical connection between the input and the output (the signal is transferred optically), an electrical fault downstream of the opto-isolator cannot affect the signal upstream and potentially harm other devices and the control console. Programmers will often install an optical isolator or splitter at the console. Using a splitter here has the added benefit of making available a DMX512 link for any DMX512 device that may be added during filming.

The second benefit is that the isolator or splitter regenerates a totally clean signal so that each output signal is strong enough, theoretically, to feed another 32 devices and run another 1000 ft. The signal can thereby be split onto multiple lines and branch out in different directions, which has some obvious practical advantages when cabling multiple lighting positions. Each new DMX512 line from the splitter must be terminated at the last device connected to it, but need not be terminated if unused.

In addition to the amplified outputs, an opto-splitter provides a THRU output (which is not amplified or optically isolated). If the THRU output is not used, *it must be terminated*. The THRU output is important, because unlike the other outputs, it is not affected by a loss of power to the opto-splitter. (Any opto-isolator or -splitter requires AC power, and must be properly grounded.) For example, if DMX512 cable feeds data to a line of fixtures and then continues on to the dimmer room, where it feeds a room full of dimmers, you would want to use the THRU output to feed the dimmer room. You would not want to risk losing signal to the dimmer room due to a power kick-out of an opto-splitter. To make life even more fool-proof, the programmer may arrange that the signal cable to the dimmer room makes a *home run* to the console, and not be routed through other lighting devices. If an opto-splitter is used, then the splitter should be located at the control console so the programmer has it in sight.

Optical splitters are a great help when they isolate signal problems geographically. This makes it much easier to find the faulty cable or device, and allows the rest of the rig to continue to operate. Without this kind of isolator, when a fault occurs in a cable somewhere in a rig, it might literally take days of testing, disconnecting sections one at a time, and replacing parts before the faulty cable is found. This is why installing opto-splitters is a very good investment of time and money. It is insurance against a potentially catastrophic delay caused by the failure of a small connector. Therefore, the strategy for installing optical splitters is to isolate each segment of the DMX512 universe, as illustrated in Figure 11.6. The THRU output on the opto-splitter should be used to daisy-chain the optical splitters together. When you are using multiple dimmer racks, it is a good idea to put each rack on an isolated line. This way, any problem with the signal will be isolated to one rack. Practitioners form opinions about the ill effects of certain equipment on the control signal, and isolate certain equipment accordingly. Some people always isolate Image 80s and 20k CD80 dimmers, for example.

It is also very important to plan the layout of optical isolators and splitters carefully when lights and devices are powered from separately derived power sources. The DMX512 cable between any two devices powered from separate sources must be optically isolated as a matter of safety, as well

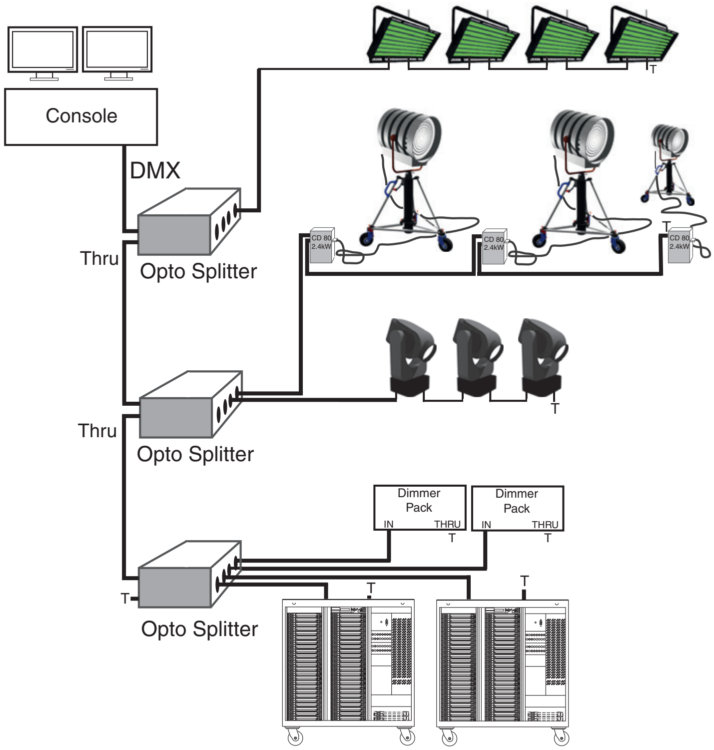


FIGURE 11.6

To provide a clean signal, and isolate potential problems, the network may be divided up so that each section of the network is supplied by a separate optically isolated data signal. Note that each dimmer pack and rack are individually isolated.

as for system reliability. Figure 11.7 illustrates how dimmer racks powered from separate sources can be kept electrically isolated using an opto-splitter.

Loss of signal

If the control console is shut off or gets disconnected from power, an opto-splitter loses power, or the DMX512 cable is disconnected, the signal will cease from that point. Failure to plan for this eventuality when the system is set up can potentially have very serious consequences when you have large numbers of dimmers under load at one time. If the dimmers lose the DMX512 signal and black out immediately, there would be a huge sudden change in load that can damage a generator, and also a big portion of the stage might be thrown into darkness. It is understandable to temporarily loose control of the lights, but a blackout is a disaster. It is also easily avoidable with proper forethought and precautions.

When a device loses its DMX512 signal, it will not necessarily just black out; most do not. Devices respond according to how they are designed and sometimes according to the settings made in their setup menu. Moving lights are typically set up to remain on and continue at the last settings sent from

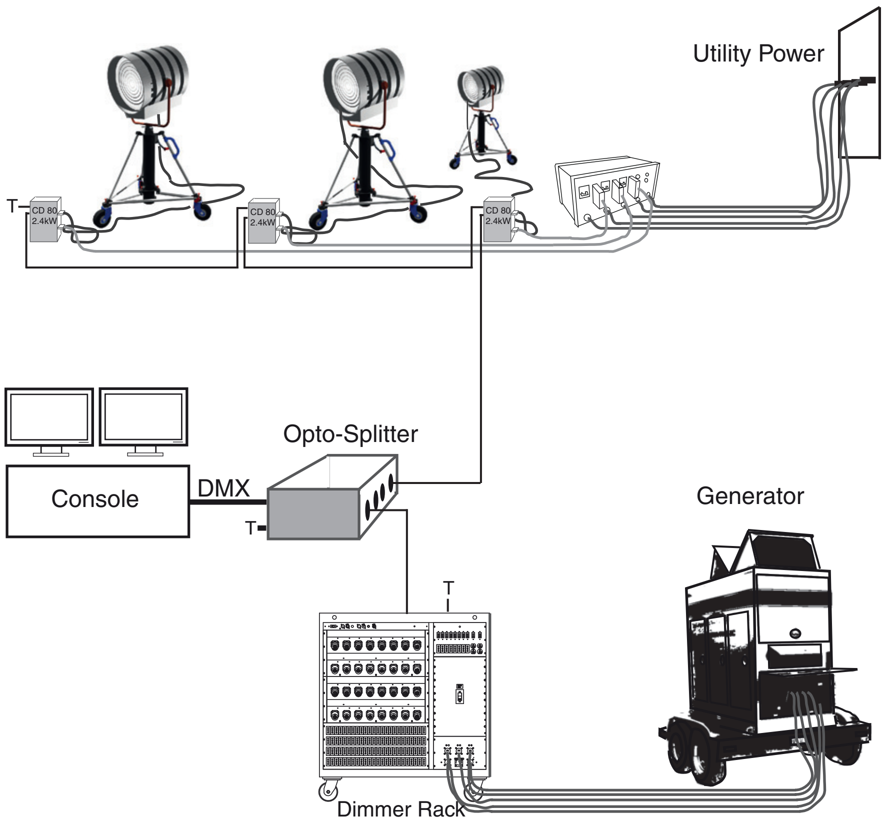


FIGURE 11.7

When DMX512-controlled lighting devices are powered from different sources, such as house power and a generator, an optically isolated repeater or splitter should be installed between them.

the console. Kino Flo DMX512 fixtures will maintain their last settings, and will shut off only with a command from the controller. Typically, DMX512 HMI ballasts and LED lights do the same. Modern digital dimmers provide a number of possible options in the event of signal loss, including:

- defaulting to a selected preset,
- holding status quo indefinitely, or
- fading to black after a delay of a selected number of minutes.

The older Strand CD80 dimmer packs can be set either to retain the last settings (status quo) for 30 min, or to black out immediately. Electricians often leave the status quo feature turned off, using the logic that if there is a problem, it is better to know about it right away, not 30 min after the fact. It is true that you have a far better chance of someone realizing the source of the problem if there is an immediate cause and effect (for example, "Well, we were moving the set wall and all of a sudden those lights went out. Oh, look, the cable got snagged."). However, when signal loss could pose a

hazard, it is essential to set up dimmers so that they maintain status quo levels with critical lights. The key is to also consider how the programmer can be alerted immediately upon signal loss. Of course the programmer will notice the problem as soon as he or she goes to change a level, or sooner if there is a chase effect or moving light working. The programmer can choose dimmer packs with noncritical lights and set them up to black out immediately. If nothing else, the programmer can set up a light at his or her station that will shut off if it loses signal. (Ideally, this test light would be connected as the last DMX512 device on the network, so that it will alert the programmer to a break anywhere in the line.) Most modern dimmer racks *can* provide alerts back to the control console via Ethernet network or RDM; however, these networks work only with a compatible console, so this option cannot always be implemented.

Another part of the strategy is to use opto-splitters (as mentioned earlier), so that if one dimmer pack has to be disconnected or swapped, the DMX512 signal is not taken offline for the remaining dimmer racks (or packs). This also isolates any problems to one trunk line of the DMX512, and makes if easy to troubleshoot. Opto-splitters typically have LED indicator lights that show if they are receiving a DMX512 signal, as do dimmer racks and other DMX512 devices. These indicators are valuable for identifying a failure and tracking down the point of failure. If you suspect a control signal failure, the first things to check are the DMX status indicator lights (1) at the control console and (2) in the dimmer room.

The control console and the critical opto-splitters should be powered through uninterruptible power supply (UPS) devices to eliminate any chance of losing signal that way. In the event of power loss, the UPS supplies power for a limited time via battery and sounds an alarm to alert everyone to the problem. If no UPS is in place, no one has any way of knowing where or why a loss of DMX control has occurred. Although a tripped alarm will disrupt production, it allows the electric crew to go right to the problem and fix it.

Another contingency to plan for is the occasional need to reboot the control console. You want to be able to do this without causing any disruption to production, and, in fact, it can usually be accomplished without anyone knowing at all. Provided that the dimmers and lights are set up to preserve status quo for at least 5 minutes, you can safely unplug the DMX512 cable from the data link, reboot the console, return to the look that is currently on stage, and reconnect the DMX512 cable without affecting any dimmer levels. However, keep in mind that if the DMX512 cable is connected when the console reboots, it will immediately clear the last command, and black out the stage. If you are using a PC as a console, you can unplug the computer; the PC DMX interface will continue to generate the last signal it received as long as it has power. You can reboot the computer if necessary, without ever losing DMX512 signal. You'll want to check the manuals for the equipment you are using to be sure that you have a plan in place to handle these contingencies.

Merger/combiner

A merger or combiner accomplishes the reverse of an optical splitter. It is used to connect more than one DMX512 controller to a single DMX512 universe. For example, if the gaffer or DP wants to experiment with the levels personally while standing on set during setup, or wants to have control over specific dimmers for a cue, the system must be able to accommodate an additional controller, with both consoles able to control the lights. Another common situation in which a second DMX512 controller can be handy is during rigging. If the show is being run on a complex high-end console, the rigging crew may not even want to deal with it. A simple board may be all that is needed for testing and focusing lights.

A “five-universe combiner” provides for up to five controllers to be connected to a single DMX512 universe. This raises the question of which of the five controllers gets command priority. The priority can be assigned to a particular port, or using a system like highest takes precedence (HTP) or latest takes precedence (LTP). HTP is typically used. A merger/combiner is an optically isolated device. Because a power interruption to the merger/combiner would cause system-wide signal loss, merger/combiners should be protected by a UPS.

Wireless DMX

Wireless DMX512 transmitters and receivers use radio waves in the 2.4-2.45 GHz bandwidth to deliver DMX512 signals without the need for cable. Wireless systems can be used for *multicasting* (broadcasting to multiple receivers), or *point-to-point* (which eliminates a cable between two points), or a combination of multicast and point-to-point. The *transmitter* (identified as Tx) converts one DMX512 signal to a high-speed broadcast data format. The *receiver* (identified as Rx) receives the broadcast and decodes it back into a clean DMX512 signal (Figure 11.8). Manufacturers also make *transceiver* units that can act as either receiver or transmitter to build flexibility into your kit. The units have multipurpose mounting brackets so that they can be mounted anywhere in the rig. Wireless DMX units are certified for use in many countries including the United States, Canada, Japan, and the European Union. The universal power supply can accept any voltage of 90-250 V for use worldwide.

Wireless DMX systems are plug-and-play. However, a little experience goes a long way in getting them to work in more challenging situations. The 2.4 GHz waveform has favorable characteristics for both range and obstacle penetration, so this band is used by many devices, including Wi-Fi networks, some cordless phones, Zigbee, and Bluetooth. Microwave ovens also operate in this frequency range and can interfere with reception. Wireless DMX systems provide various strategies for avoiding radio frequency (RF) interference and sharing the spectrum so as not to cause interference with other devices, which may also be mission-critical. Central to this is the use of the Adaptive Frequency Hopping Spread Spectrum (AFHSS). This method of transmission rapidly switches the

FIGURE 11.8

Show DMX transmitter and receiver.

(Courtesy Show City Theatrical.)

signal among many channels in a pseudorandom sequence known to both the transmitter and receiver. The benefits of this arrangement are that the transmission is highly resistant to narrowband interference, and it creates minimal interference for other communications devices. The AFHSS transmission appears merely as an increase in background noise. Because the signal is constantly hopping, it cannot be intercepted.

In addition to AFHSS, wireless DMX systems allow for various adjustments that the user can make to help work around interference; however, users often find that the default settings are entirely adequate. Transmitters have adjustable power output. The power should be set just high enough to assure a consistent signal. Using a lot more power than is necessary can actually cause a distorted signal. The user can also define the range of DMX addresses broadcast in order to shorten the broadcast burst. For example, if a user needs only 128 DMX channels, the transmitter can limit transmission to just that range of channels and cut transmission time to a quarter of what it would otherwise be. The shorter the burst, the greater the system's resistance to interference.

The wireless DMX transmitter has an adjustable bandwidth, so it can be set up to use the full spectrum or only a portion of the spectrum, so as to avoid interference between transmissions. Before installing a wireless DMX system, the user can learn a great deal about the RF environment by analyzing the spectrum to pinpoint existing devices operating within range, and to determine what channel they are using and what part of the spectrum is less heavily used. A spectrum analyzer (such as Wy-Spy) shows on a visual display the strength and frequency spectrum occupied by RF activity within range. You can also survey Wi-Fi access points using a laptop and free software available from the Internet. This shows frequency and signal strength of Wi-Fi traffic; however, your laptop will not identify non-Wi-Fi devices that are using the spectrum, as a spectrum analyzer will. There are 11 overlapping channels available in this spectrum. Channels overlap with adjacent channels, but channel 6 will not interfere with channel 11, for example. Assigning the wireless DMX system to a relatively quiet set of channels, away from other mission-critical transmission frequencies, may improve reliability.

Another very effective way to cut through RF interference, especially when transmitting longer distances point to point, is to use directional antennas for the transmitter and receiver. These must be line-of-sight transmissions (which do not penetrate walls). Directional antennas have a balloon-shaped transmission/reception profile with greater range (Figure 11.9). Omnidirectional antennas send the signal out in all directions—360° and have less range. There are a variety of omnidirectional and directional antennas available for different situations. Experience has shown that in some locations it takes every trick in the book to get a solid signal, but it can almost always be done. Walking the set with a portable signal-strength tester (e.g., the Ugly Box) is a good way to find the best locations for receivers. Raising the transmitter antenna higher in the air, and moving it away from walls that cut down its effective angle of transmission can take better advantage of the antenna's range.

In large spaces where radio range is a challenge, a *booster* can be attached to the transmitter or receiver to extend the effective range. A boost can help drive the signal into reflective corners and hard to reach areas. A *repeater* unit is one that receives a signal, cleans it up with some signal processing, and then transmits it afresh. It can be used to send the signal around corners when the ultimate receiver is not in the line of sight from the transmitter. Repeater units allow you to build a system with unlimited range. Some equipment is designed with the proper protections for outdoor use.

W-DMX also makes a 19″ rack-mounted wireless DMX transmitter that can broadcast up to 32 DMX512 universes simultaneously. It is connected to the control console via ArtNet or the ACN

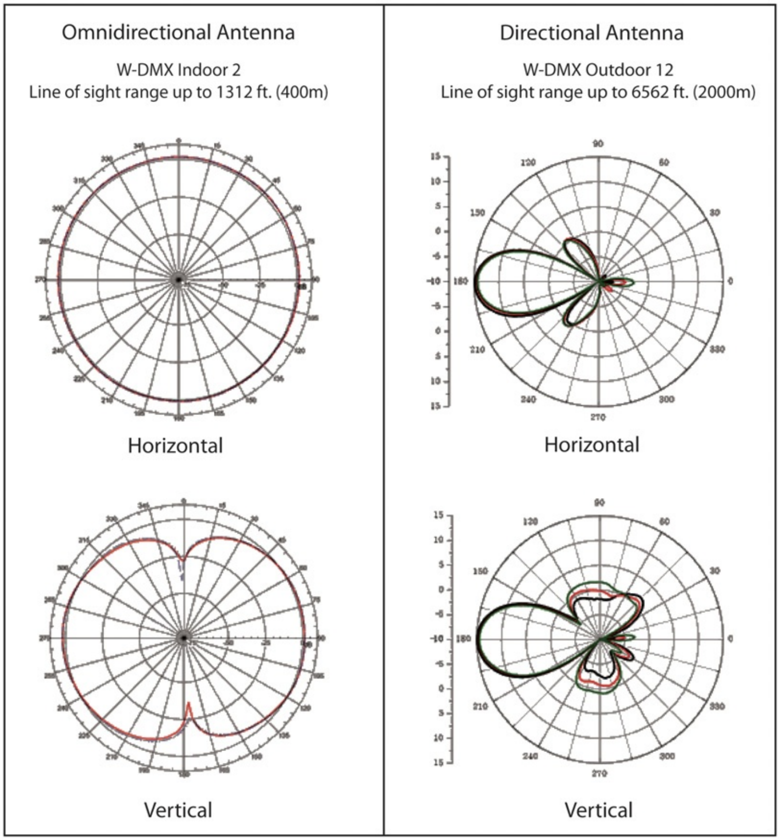


FIGURE 11.9

Wireless DMX antenna patterns: (A) omnidirectional antenna, (B) directional antenna.

(Courtesy W-DMX)

control protocol. At this writing, it appears the next generation of moving light fixtures will feature built-in wireless DMX receivers, for which this type of transmitter would be ideal.

There are currently no standards for wireless DMX data formats, and as a result no products are compatible from one manufacturer to another, even when they are using very similar technology. Technicians who invest in wireless gear just pick a brand and stick with it. In fact, because programmers often rent gear from each other, many top programmers have agreed to invest in the same gear.

DMX512 Testing

When troubleshooting a large network, it is extremely helpful to have test equipment. A DMX line tester plugs into the control cable and tells you whether you are receiving a signal (Figure 11.10A). More sophisticated testers like GAM Command II (GAM), Gizmo (Doug Fleener Design)

FIGURE 11.10

DMX512 testers: (A) DMXTSTR. An LED lights up if a signal is present (Courtesy Doug Fleenor Design, Inc.); (B) GIZMO (Courtesy Doug Fleenor Design, Inc.); (C) X-MT-120 Swisson DMX Tester. (Courtesy Mark Miller, MARIOFAMOUSFOTOGRAPHY, Swisson of America, Corp.).

(Figure 11.10B), Swisson XMT-120 (Swisson) (Figure 11.10C), DMXter (Goddard Design) perform a whole host of helpful diagnostic functions. These testers can do things like:

- Generate a DMX512 signal for one entire universe
- Read and store looks and sequences
- Control individual or groups of channels

- Receive and read out the channel levels
- Analyze the DMX512 signal
- Test cables for continuity, shorts, and proper wiring
- Run diagnostic tests on each channel
- Run moving light tests

DMX: Past, present, and future

A little history helps show the trajectory of control technology. Since its inception in the mid-1980s, DMX has evolved and matured. Before that time, manufacturers were each developing their own proprietary control technology, and it became clear that a standard was needed. The Engineering Commission of the United States Institute for Theater Technology, Inc. (USITT) published the first standard, titled "DMX512 Digital Data Transmission Standard for Dimmers and Controllers" in 1986. At the time, the new standard was specifically for dimmers. Many manufacturers did not want to use DMX512 to control their automated lights. But writing a new standard that satisfied all parties was a near-impossible task (even creating the DMX512 standard was reportedly quite a struggle). Despite concerns by some that it would not be fast enough, the DMX512 protocol was soon widely adopted for moving lights and other devices. The 1990 standard set out the parameters for the *physical layer* (the hardware and wiring), the underlying communication standard called TIA/EIA-485, and the DMX512 data protocol. It specified such things as use of copper wire suitable for high-speed data transmission, the use of a 5-pin XLR connector, and the pin configuration. At that time, pins 4 and 5 were reserved for a future implementation of a second data link, but no specifications were provided.

After many years of work, ESTA authored an improved standard, and in 2004 the ANSI board of standards approved the DMX512-A standard. The new standard was entitled "USITT DMX512-A Asynchronous Serial Digital Data Transmission Standard for Controlling Lighting Equipment and Accessories." This standard broadened the DMX512 standard to allow for several possible methods of bidirectional communication. Many of the features made possible by the DMX512-A standard have yet to be fully implemented by manufacturers, but the standard is in place for when they do.

In previous standards, each packet of data was preceded by a start code, which was always all zeros. The DMX512-A standard specifies Alternate Start Codes that can be used to tell a DMX receiver that the following packet of data has a different purpose than providing DMX values. This opens up a world of possibilities for requesting information from a lighting device (for example, the settings in the setup menu), and for receiving ASCII text back from the fixture. The integrity of data sent to a lighting device can be checked by transmitting a checksum value (several bytes of data are transmitted and then their sum is transmitted; the receiver sums the same data and compares the sum to the checksum value it receives, and if there is a discrepancy, it sends a message back to the console requesting that the information be sent again). In this way, the console can be sure that a software upgrade was received correctly. The 2004 standard provides a way for manufacturers to register proprietary Alternate Start Codes; this way, proprietary functions can be used within the overall standard.

Another step forward was the creation of *enhanced function topologies*. This specification finally set down standards for the use of both pairs of control wires, the primary and secondary links that were originally specified in the 1990 DMX512 standard. There are four enhanced function topologies that are provided:

EF1	Primary link:	half duplex, can send and receive (e.g., via RDM)
	Secondary link:	not connected
EF2	Primary link:	sends data
	Secondary link:	receives data
EF3	Primary link:	sends data
	Secondary link:	half duplex, can send and receive
EF4	Primary link:	half duplex, can send and receive (e.g., via RDM)
	Secondary link:	half duplex, can send and receive (e.g., via RDM)

Half duplex means that data can only travel one way at a time—like a walkie-talkie. Full duplex means that data can be sent and received at the same time. EF2 uses the primary and secondary data links together in full-duplex mode. There is a great deal of up-to-date information available from the ESTA Web site concerning lighting control standards.

Remote Device Management (RDM)

Many times, a bleary-eyed programmer working into the wee hours of the morning has thought to him- or herself: "If only these lights could talk back to me! Then I would know why nothing I do is fixing the problem. Curse you, DMX!" After many years of development by the good people at ESTA's Control Protocols Working Group, a new standard was adopted to answer just this problem. Remote Device Management (RDM) opens up a two-way dialog between a DMX/RDM control console and RDM-enabled DMX devices. RDM totally changes the way the programmer interacts with the devices. DMX addresses and some fixture setup parameters can be set from the console without having to go to the actual device. No longer does the programmer have to manually add and patch the fixtures into the console. With RDM, the controller goes through a process called "discovery" to seek out intelligent life—RDM-capable devices. In this process, the controller learns the unique identification number (UID) for each RDM-capable device connected to it. A UID is a unique number given to each device at the factory that cannot be changed. Once a device is discovered, the controller can send and receive messages to and from that device using its UID. Upon discovery, the console requests device information and each device then tells the controller a great deal of information about itself, including the product model ID, software version, slot footprint (number of consecutive DMX512 slots it uses), DMX512 personality, start address, number of sensors, and so on. This way, the console knows everything about the device. The patching process becomes automated, and the probability of accidentally overlapping addresses is eliminated.

Every device has its own list of messages that it can send to the console to alert the programmer of its status (address and settings), of its condition (sensor readings, component failures), of the integrity of the data (data transfer failures), and other necessary information. Sensor readings include important health diagnostics like temperature, current, and voltage. The list of commands and response messages that can be created is long, and will get longer as more and more devices adopt this technology.

RDM was cleverly designed to share the same two wires used by DMX512A, so the wiring remains unchanged, and RDM and non-RDM devices may work simultaneously on the same DMX512 network. The network speed is also unchanged. However, any device that generates a signal, such as an opto-splitter, must be RDM-capable in order to carry signals in both directions. And of course the console has to be RDM-capable.

Although DMX512 is a totally one-way conversation, DMX512 with RDM is not exactly a free two-way conversation, either. DMX/RDM is like a single-lane street, where traffic may flow in only one direction at a time. RDM provides the traffic lights needed to accommodate two-way traffic. An RDM enabled console controls the flow of data; it queries the RDM fixtures and then switches from transmitting to receiving during the exact millisecond in which the RDM device responds. The console processes and displays the message for the programmer. In order to prevent packets of data coming to and from the DMX512 devices from colliding, the system is set up so that RDM devices speak only when spoken to. The console has to ask the device if it has anything to report, and then the device is given a very specific time window to say what's on its mind. If a device generates an error message it stores the error message in a queue, waiting to be prompted.

There is of course a much faster, more reliable communication system capable of carrying several magnitudes of more data in two directions simultaneously: it's called Ethernet. Ethernet networks and RDM are not necessarily competing technologies, however. The two technologies are complementary, operating in two different portions of the communication highway, with DMX/RDM being the last mile to the device.

Ethernet networks

Manufacturers in entertainment control have for some time seen advantages to implementing control protocols using Ethernet networks instead of—or as well as—DMX512. Ethernet standards were developed in the computer industry in order for computers to communicate with one another and with other digital devices. Communication is extremely fast, flows two ways simultaneously, and has been designed with a very high degree of reliability. A single Ethernet cable can carry many universes of DMX512. Because Ethernet is a universal technology, instead of something developed strictly for the entertainment world, network hardware is widely available (at any computer store or home improvement center) and inexpensive. Initially, manufacturers of lighting control equipment developed their own proprietary protocols for Ethernet-based communications. This allowed the lighting console to send DMX512 data over a proprietary system to moving lights or dimmer racks made by the same company. ETCNet2, SandNet, and StrandNet are examples. Similarly, the most sophisticated control consoles use an Ethernet-based communication protocol to allow for greater system expandability. A console like the Hog III does not provide the DMX512 data link at all. Instead, it communicates using an Ethernet-based system (Hognet is Highend Systems' proprietary protocol). The console acts as a *network server*. It communicates with one or more DMX512 processor units, which become *client* devices. The processors provide multiple DMX512 data links to communicate DMX512 (and one day, RDM) to and from the lighting devices. Architecture for Control Networks (ACN) was accepted as a standard in 2006. It is a suite of protocols designed for distribution of data and control of entertainment devices using a network. ACN is a software protocol. The standard does not specify any hardware requirements, and it doesn't need to, because it uses the same infrastructure and hardware as any computer network—Ethernet cables, routers, switchers, bridges, hubs, and so on. ACN is a plug-and-play system. It automatically discovers the lights connected to it and queries the programmer regarding how he or she wants to configure them. It uses Device Management Protocol (DMP) to control, monitor, and manage all devices it sees.

Every ACN-compliant device has a Device Description Language (DDL) file that provides the console with all of the information it needs to automatically configure and control the new device. Multiple consoles can be connected to the same network and either work on the same show simultaneously or control discrete parts of the overall network. Ethernet-based systems provide many benefits, especially when working on a really large production:

- A single Ethernet cable can carry data for many DMX512 universes at once. 10baseT Ethernet can carry about 20 DMX512 universes; 100baseT Ethernet can carry about 200; and 1000baseT, also known as gigabit Ethernet, can carry about 2000.
- The network is infinitely expandable. Theoretically, any number of DMX512 universes can be created for a single console by simply adding DMX512 processors.
- A backup hard drive can also be added as a client in case the main console crashes.
- A PC can be added as a client running the PC version of the console software. Programmers can set up a wireless router and use a tablet PC (a portable laptop with a touch screen) to have a totally wireless mobile additional control console that is able to access all console functions remotely. The programmer can bring the tablet right on set to work with the DP or gaffer. A networked PC acts as a second console—handy anytime you have to work two sets at once, such as when one set is being prelit while the other is being shot. Because the PC is just a client, all work is saved on the server—the main console—so if the PC loses the signal, everything still continues to work. There are even iPhone/iPod touch applications available to run supported consoles from the handheld device using the network.
- Additional control consoles working on the same show can be added as clients onto the network. This allows two or more consoles to work simultaneously and to save to a single showfile. On a show which has moving lights and conventional lights, it is ideal to have a console and dedicated programmer for each, and to save to one show file. When two production units are filming simultaneously, the show files can archived to the main console, so everyone is always working from the same information.
- This idea can be expanded to support client DMX512 processors in other sets—even in other soundstages—without moving the control console. Because the main control console will move with the first unit filming crew, the network allows the programmer to support lighting activities (such as rig testing and prelighting) in other sets without necessarily adding an additional console and programmer for those minor tasks.
- A media server can be added as a (ACN) client. Ethernet is ideal for computer-to-computer communications. The control console becomes a tool to manipulate layers of video in the media server, and control video playback to monitors or projectors.

It appears that for some years into the future, Ethernet and DMX512 will be working hand in hand. DMX512 still possesses certain advantages. DMX512 cables are more robust than CAT5 cables (although "ruggedized" CAT5 cables are now available). Ethernet uses a star topology, with every device requiring its own cable to be run back to a distribution hub; DMX512 uses a bus topology in which devices are daisy-chained together, which is a very workable system for devices hung in a line in the rig. Though modern dimmer systems offer networking capability, they will also continue to offer DMX512 (and RDM), allowing a system to be designed for whatever level of sophistication is appropriate for the job at hand.

ADVANCED AUTOMATED DEVICES

Moving lights (automated luminaires)

A long tradition of showmanship in rock-and-roll lighting brought us moving lights, which have come to be used in all segments of entertainment—theater, trade shows, television broadcasts, and live events of all sorts. Automated luminaries (generally called moving lights or simply “movers”) are capable of creating breathtaking effects in the hands of a creative designer and a skilled lighting control programmer. Typically, in concert applications, an array of moving lights are choreographed in coordinated patterns to make sweeping pans and flourishes, weaving beams of light into patterns in the (fogged) air and moving colored projections across the stage surfaces. In motion pictures and television, moving lights are used for lighting effects of all kinds. To give just a few examples, moving lights have been employed to simulate the changing beam of a movie projector, to animate a static image of the ocean on a translight, as an overhead helicopter light, to emulate passing car headlights, or simply as a remotely controlled spotlight. An automated fixture can also be handy in situations where the architecture or logistics prevents a lighting technician from getting to the lights easily to adjust them for each set up. For example, if dozens of background artists would have to be moved in order for the lighting crew to bring a lift into the set, a great deal of time can be saved by using a light with remote pan, tilt and focus.

The operation of moving lights is complex, requiring an appropriately sophisticated control console and the skills of a programmer for whom this is a specialty. The lights have dozens of features (an example was shown in Table 11.6). Standard features on a profile spot fixture include:

- Pan and tilt
- Zoom and focus. Zoom controls how narrowly concentrated the beam is. Focus defines the sharpness of a projected image, and beam edge.
- Variable iris, which changes the diameter of the beam without changing brightness.
- Dimming and blackout
- Variable strobe shutter
- CMY (cyan, magenta, yellow) color mixing, which allows the luminaire to create light in a wide range of colors.
- Color correction wheel, which allows daylight-balanced arc lamp fixtures to adjust to any color temperature by adjusting the amount of CTO correction.
- Color wheel, which provides a number of specific colors that can be customized for the job at hand.
- Gobo wheel, which provides a selection of different patterns that are used to project graphic patterns or textures on stage surfaces, and—by carving a pattern into the beam—it is endowed with a streaming quality.
- Rotating gobos, which can be programmed to rotate with adjustable speed and direction. By setting a stationary gobo with a rotating one, moving texture effects can be created that give an impression of a wide range of graphic or impressionistic effects, including moving water, fire, shifting dappled light, and so on.

A typical moving light has six or more gobo slots. The gobos can be exchanged as required by the lighting designer. Each manufacturer provides a particular set of gobos with their light, so when a

lighting designer or gaffer orders a particular light, he or she might be expecting to have access to particular gobos. However, some rental houses may use different gobos in their lights, or may not install the gobos in the same slot number from others. This can lead to unhappy surprises on set and programming headaches. It is a good idea to specify which gobos you want, and in which order, so that all the lights are configured in the same way, with the gobos you need. Rental managers are used to customers specifying exactly how they want the lights delivered. It is common practice in the rock-and-roll world.

Selecting moving lights

The number of different moving lights on the market today is truly mind-boggling. The manufacturers' Web sites provide detailed descriptions, support, and really great video demonstrations. It may be very helpful to have a conversation with your programmer about the effects you intend to create. Programmers have experience with a wide variety of lights and will be able to tell you which lights are most appropriate and what is available in the local market. If you are unsure which mover is best, do a test or demo. Rental managers are very willing to loan movers for tests and demos. It is not a bad idea to compare different brands side by side. Table 11.7 (compiled by programmer Scott Barnes) lists many specifications that are important in real applications.

Moving lights can be broken down into major categories as follows:

Profile spotlight versus wash fixture. A profile spot has a relatively narrow beam, which can be used to project gobos. Typically, the beam can be zoomed from around 10° to around 30° or more, depending on the model. A wash fixture has a much wider field than a profile fixture, and is therefore not as bright. They are used for covering larger areas with colored light. Wash fixtures do not have gobos and projections.

Moving yoke or moving mirror. A moving yoke fixture has a very wide range of motion. A typical yoke-mounted light can rotate 540° and tilt 270°. A moving mirror fixture like the Cyberlight has much less range of movement (170° or 180° of pan and 110° of tilt). However, a moving mirror can move the beam much faster than a moving yoke fixture. When considering speed, it is important to consider how close the lights are to the subject. The further away the lights are placed, the faster the beam travels across the stage (fewer degrees of rotation for the same amount of beam travel). For filming, we tend to need to place the lights closer, and this results in a slower speed of travel across the ground.

Tungsten lamp versus metal halide. The vast majority of moving lights have daylight-balanced metal-halide arc lamps—short-arc HTI, HMI, or MSR lamps, which typically have a color temperature of 6000-8000 K and a CRI of 75-80. Many moving lights have a color correction filter that can be used for 3200 K filming (if not, you can add CTO to the color wheel). Nonetheless, in certain situations, it may be desirable to use a tungsten light source, especially if the light may be used to light the performers (as opposed to just lighting the air). Tungsten lamps can be dimmed electrically; metal halide lamps are dimmed using a mechanical dimmer. On the other hand, metal halide lamps put out a great deal more light per watt.

Wattage. Moving lights tend to come in standard wattages. Most manufacturers make metal halide arc fixtures in 250, 300, 575, 700, 1200, and 1500 W wash and profile fixtures. 1800 and 2500 W fixtures are also becoming more commonplace. Tungsten fixtures are typically 575, 750, or 1000 W.

Indoor use or outdoor use. Lights that are rated for outdoor use are designed to be subjected to the elements for long periods of time. I have heard stories from programmers who got caught

Table 11.7 Moving Lights: Capabilities and Specifications

FIXTURE NAME	MANUFACTURER	TYPE	YOKE or MIRROR	CHANNEL COUNT	LAMP	WATTAGE	POWER	FAN NOISE	MOTOR NOISE	COLOR CORRECTION	COLOR MIXING	FIXED COLOR WHEEL	STATIC GOBOS	ROTATING GOBOS	BEAM EFFECTS	FROST or DIFFUSER	ZOOM	STANDARD LENS (Expandable Lens)	IRIS	FRAMING SHUTTERS	SPEED	ON BOARD BATTERY	WEIGHT
Alpha Profile 1500	Clay Paky	Hard Edge	Y	41	Arc	1500w	208v	MED	LOW	VARI	CMY	6	8	6	1	Y	Y	6°-56°	Y	Y	***	X	110 lbs
Alpha Spot HPE 1500	Clay Paky	Hard Edge	Y	40	Arc	1500w	208v	MED	LOW	VARI	CMY	6	8	12	2	Y	Y	6°-56°	Y	N	***	X	110 lbs
Alpha Profile 1200	Clay Paky	Hard Edge	Y	35	Arc	1200w	BOTH	MED	LOW	VARI	CMY	6	8	6	2	Y	Y	10°-30°	Y	Y	***	X	86 lbs
Alpha Spot HPE 1200	Clay Paky	Hard Edge	Y	28	Arc	1200w	BOTH	MED	LOW	VARI	CMY	7	8	12	3	Y	Y	10°-40°	Y	N	***	X	86 lbs
Alpha Spot HPE 700	Clay Paky	Hard Edge	Y	29	Arc	700w	BOTH	LOW	LOW	FIX	CMY	8	8	7	1	Y	Y	14.7°-47°	Y	N	*****	X	50 lbs
Alpha Spot HPE 300	Clay Paky	Hard Edge	Y	27	Arc	300w	BOTH	LOW	LOW	FIX	CMY	8	8	7	1	Y	Y	10°-40°	Y	N	*****	X	47 lbs
VL3000	Vari*lite	Hard Edge	Y	28	Arc	1200w	208v	MED	MED	VARI	CMY	6	0	13	1	N	Y	10°-60°	Y	N	***		91 lbs
VL3500	Vari*lite	Hard Edge	Y	31	Arc	1200w	208v	MED	MED	VARI	CMY	6	6	5	0	N	Y	10°-60°	N	Y	***		91 lbs
VL1000TS (or TSD)	Vari*lite	Hard Edge	Y	27	Tungsten	1000w	BOTH	LOW	LOUD	NONE	CMY	0	0	5	0	Y	Y	19°-70°	N	Y	**		70 lbs
VL1000TI	Vari*lite	Hard Edge	Y	19	Tungsten	1000w	BOTH	LOW	LOUD	NONE	CMY	0	0	5	0	Y	Y	19°-70°	Y	N	**		70 lbs
VL1000AS	Vari*lite	Hard Edge	Y	27	Arc	575w	BOTH	MED	LOUD	NONE	CMY	0	0	5	0	Y	Y	19°-70°	N	Y	**		70 lbs
VL1000AI	Vari*lite	Hard Edge	Y	19	Arc	575w	BOTH	MED	LOUD	NONE	CMY	0	0	5	0	Y	Y	19°-70°	Y	N	**		70 lbs
Mac 2000 Performace	Martin	Hard Edge	Y	31	Arc	1200w	BOTH	MED	MED	VARI	CMY	0	0	5	3	N	Y	12°-31° (18°-41°)	Y	Y	*		87 lbs
Mac 2000 Profile	Martin	Hard Edge	Y	24	Arc	1200w	BOTH	MED	MED	VARI	CMY	4	8	5	0	Y	Y	12°-29° (14°-35°)	Y	N	*		84 lbs
Mac 700 Profile	Martin	Hard Edge	Y	31	Arc	700w	BOTH	MED	MED	VARI	CMY	8	9	6	2	Y	Y	16°-30°	Y	N	**		76 lbs
Mac III	Martin	Hard Edge	Y	30	Arc	1500w	208V	MED	MED	VARI	CMY	7	0	10	2	N	Y	11.5°-55°	Y	N	***	X	118 lbs
BAD BOY	PRG	Hard Edge	Y	42	Arc	1200w	208v	LOUD	LOUD	FIX	NONE	28	0	14	0	Y	Y	7°-56°	Y	N	***		167 lbs
SHOWGUN 2.5	High End	Hard Edge	Y	30	Arc	2500w	208v	LOUD	MED	VARI	CMY	0	0	4	0	N	Y	9°-18°	Y	N	**		140 lbs
SHOWGUN	High End	Hard Edge	Y	30	Arc	2000w	208v	LOUD	MED	VARI	CMY	0	0	4	0	N	Y	9°-18°	Y	N	**		140 lbs
Cyberlight Turbo	High End	Hard Edge	M	20	Arc	1200 w	208v	LOUD	MED	NONE	CMY	7	7	4	7	Y		13°-22° (16°-36°)	Y	N	*****		110 lbs
Cyberlight 2.0	High End	Hard Edge	M	28	Arc	2000w	208v	LOUD	MED	NONE	CMY	8	8	4	8	Y		13°-22° (16°-36°)	Y	N	*****		99 lbs
Studio Spot	High End	Hard Edge	Y	24	Arc	575w	BOTH	LOUD	LOUD	NONE	NONE	10	0	10	0	Y	N		Y	N	**		56 lbs
Studio Spot CMY	High End	Hard Edge	Y	24	Arc	575w	BOTH	LOUD	LOUD	NONE	CMY	0	0	10	0	Y	Y	18°-30°	Y	N	**		56 lbs
Technobeam	High End	Hard Edge	M	18	Arc	375w	BOTH	LOUD	MED	FIX	CMY	12	0	7	4	Y	N		N	N	*****		42 lbs
Alpha Wash 1500	Clay Paky	Wash	Y	26	Arc	1500w	208v	MED	LOW	VARI	CMY	12				Y	Y	10°-72°	N	N	***	X	100 lbs
Alpha Wash 1200	Clay Paky	Wash	Y	16	Arc	1200w	BOTH	MED	LOW	VARI	CMY	4				Y	Y	11°-55°	N	N	***	X	79 lbs
Alpha Wash 700	Clay Paky	Wash	Y	24	Arc	700w	BOTH	LOW	LOW	FIX	CMY	8				Y	Y	9°-50°	N	N	*****	X	45 lbs
Alpha Wash 300	Clay Paky	Wash	Y	17	Arc	300w	BOTH	LOW	LOW	FIX	CMY	8				Y	N		N	N	*****	X	40 lbs
VL3500 WASH	Vari*lite	Wash	Y	19	Arc	1200w	208v	MED	MED	VARI	CMY	10				N	Y	4:1	Y	N	***		96 lbs
VL3500 WASH FX	Vari*lite	Wash	Y	22	Arc	1200w	208v	MED	MED	VARI	CMY	10	0	4		0	Y	4:1	N	N	***		97 lbs
VL500 WASH	Vari*lite	Wash	Y	13	Tungsten	1200w	208v	LOW	MED	NONE	CMY	0				Y	N		N	N	****		43 lbs
VL500A WASH	Vari*lite	Wash	Y	13	Arc	700w	BOTH	LOW	MED	NONE	CMY	0				N	N		N	N	****		43 lbs
VLX WASH	Vari*lite	Wash	Y	23	LED	7x 120w	BOTH	LOW	MED	NONE	RGB	0				N	Y	23°-58°	N	N	**		62 lbs
Mac 2000 Wash	Martin	Wash	Y	21	Arc	1200w	BOTH	MED	MED	VARI	CMY	8				N	Y	12°-37° (13°-40°, 80°-95°)	Y	N	*		84 lbs
Mac 2000 Wash XB	Martin	Wash	Y	21	Arc	1500w	208v	MED	MED	VARI	CMY	8				N	Y	12°-37° (13°-40°, 80°-95°)	Y	N	**		76 lbs
Mac 700 Wash	Martin	Wash	Y	23	Arc	700w	BOTH	MED	MED	VARI	CMY	8				Y	Y	12.5°-66°	N	N	**		71 lbs
TW1	Martin	Wash	Y	20	Tungsten	1200w	BOTH	MED	MED	NONE	CMY	0	0	0	0	N	Y	20°-41° (14.5°-27°, 97°-105°)	N	N	***		60 lbs
Studio Color	High End	Wash	Y	16	Arc	575w	BOTH	LOUD	LOUD	FIX	CMY	5				Y	N		N	N	**		85 lbs
SHOWPIX	High End	Wash	Y	70	LED	127X3w	BOTH	LOUD	MED	NONE	RGB		MEDIA								****		108 lbs
STUDIOpix	High End	Wash	Y	70	LED	61x3w	BOTH	LOUD	MED	NONE	RGB		MEDIA								****		46 lbs
Alpha Beam 1500	Clay Paky	Beam	Y	27	Arc	1500w	208v	MED	LOW	VARI	CMY	6	8	6		Y	N		Y	N	***	X	88 lbs
Alpha Beam 700	Clay Paky	Beam	Y	26	Arc	700w	BOTH	LOW	LOW	FIX	CMY	8	8	7		Y	N		Y	N	*****	X	45 lbs
Alpha Beam 300	Clay Paky	Beam	Y	18	Arc	300w	BOTH	LOW	LOW	FIX	CMY	8	8	0	0	Y	N		N	N	*****	X	42 lbs
SHOWBEAM 2.5	High End	Beam	Y	32	Arc	2500w	208v	LOUD	MED	VARI	CMY	3			1	N	Y	11°-33°	N	N	**		146 lbs
Studio Beam	High End	Beam	Y	16	Arc	1000w	BOTH	LOUD	LOUD	NONE	CMY	0				0	Y	15°-30°	N	N	**		49 lbs
DL.2	High End	Digital	Y	170	Video	300w	BOTH	LOUD	MED	ONBOARD MEDIA SERVER							Y	1.8-2.4:1			**		118 lbs
DL.3	High End	Digital	Y	170	Video	330w	BOTH	LOUD	MED	ONBOARD MEDIA SERVER							Y	1.8-2.4:1 (Long, Ultra Long, and Wide)			**		140 lbs

in monsoon rains while using (indoor-rated) moving lights outside. Not only were the lights unharmed, but they continued to operate. The programmer put the lights in a continuous ballyhoo, so rainwater could not collect inside the fixtures. Such antics aside, outdoor-rated lights provide the needed International Protection rating (IP rating) to ensure reliable use in the elements (see Appendix E).

Beyond these general categories, there are other important distinctions between different moving lights. These include: unique features, weight, the amount of noise they make, brightness (efficiency of the optical train), appearance, and price. One moving light technician I know uses a "coolness-to-weight ratio" to evaluate the usability of moving lights. He has devised an equation that divides the number of cool tricks a given light can do by its weight. A heavy fixture had better been able to perform a lot of cool tricks or it gets a poor score. A light like the Clay Paky Alpha 700 (Figure 11.11) is fast, bright, quiet, and—best of all—lightweight, so it gets a very high sore on the "coolness-to-weight ratio."

Possibly the most critical difference, when using lights close to microphones, will be noise. Most moving lights use fans, except for a couple, like High End System's Studio Color 575, that is convention-cooled. They also have motors and moving parts that whir and buzz and chatter a little. Some lights are designed for use in theatrical venues with quieter motors (see Table 11.7 for some data). Some also use baffles with noise-absorbing insulation to quiet acoustic noise.

Another factor that affects the noisiness of a light fixture is the need for fans. The majority of moving lights use an arc lamp, which generate more concentrated heat than tungsten fixtures do. They always employ an infrared reflector, also known as a hot mirror, in front of the lamp to prevent the moving parts from overheating. This creates considerable heat buildup and is a big reason that fans are required. Lights that use an incandescent lamp, on the other hand, sometimes require little or no forced-air cooling. When stationary, they are silent. The Vari-Lite VL1000 (Figure 11.12) and the ETC Source Four Revolution (Figure 11.13) are examples of tungsten moving lights.

FIGURE 11.11

Clay Paky Alpha Beam 700 (far right) and Alpha Spot HPE 700 (second from right). The large lights further down the row are SHOWBEAM 2.5 by High End Systems.

(Courtesy Mike Bauman.).

FIGURE 11.12

Vari*lite VL1000.

*(Courtesy Vari*lite.)*

FIGURE 11.13

The Source Four Revolution is designed for very quiet theatrical settings, where fan and motor noise are unacceptable.

(Reproduced by permission of Electronic Theatre Controls, Inc.)

They cannot strobe, as a doused light typically can, but the lamp can be electronically dimmed, and runs quietly.

The ETC Source Four Revolution takes a different approach than most automated lights. It can be thought of as an extremely capable, silent, automated theatrical spotlight, as opposed to a razzle-dazzle concert light. It is one of the quietest operating fixtures. The pan and tilt mechanisms are belt-driven to avoid the chatter of gears, it uses ETC's QXL incandescent lamp, and it is large enough that heat is dissipated well, so the cooling system is low velocity and ultra-quiet. The Revolution offers a limited number of essential effects features. It incorporates 15-35° zoom, adjustable focus, a built-in 24-frame color-scroller, and offers two "bays" or slots for effects modules. Modules are auto-sensing, plug-and-play. They include a choice of (any two) of the following: automated iris, automated framing shutters (each of four shutters that can be rotated as much as 90°), three static gobos, or three rotating gobos. Replacing the lamp on the Revolution can be accomplished with one hand, in a couple seconds. This is quite unlike most moving fixtures, which often require an involved procedure.

Moving lights are also distinguished from one another by special features. Gaffers especially like framing shutters. Shutters make straight cuts into the left, right, top, and bottom of the beam and can be rotated and moved to any angle—an automated version of the shutters on an ellipsoidal spotlight. This is great for cutting the light right where you want it—onto a bounce board, for example. The

framing system on the Alpha 1200 profile is unique, in that each shutter can eclipse the entire beam. It can therefore be programmed to make interesting reveals like a sliding door.

Features such as image shake, animated gobos, and rotating prism can be an important part of the alchemy the programmer uses to create certain lighting effects. For example, the shake feature can give the impression of a machine malfunctioning (which happens at some point in pretty much every science fiction movie).

The PRG Bad Boy is 1200 W spot unit with a large front lens and exceptional 8× zoom capability (7-56°). This gives it a very distinctive large bright beam (Figure 11.14). According to PRG, the lamp can also be boosted to 1400 W. The pan, tilt, and zoom are exceptionally fast for a moving-yoke fixture, which enables some really breathtaking effects. The Clay Paky Alpha Beam 1500 is also known for its exceptionally bright beam and very fast motors.

Some moving lights simply look cool. When moving lights are going to be on-camera elements, this may even be the overriding consideration. The Vari*Lite VL500 has a front end that looks like the fan blades of a jet engine (Figure 11.15). Increasingly, moving lights are available with features like RGB LEDs encircling the lens, which can be programmed to make all kinds of chase, strobe, and pattern effects, so the light fixture itself becomes a visual element. The ShowBeam 2.5 (by High End Systems) is 2500 W profile spot with this distinctive look (Figure 11.11). This light is also

FIGURE 11.14

An Oasis concert showered with powerful shafts of light from eight PRG Bad Boys.

(Courtesy PRG.)

FIGURE 11.15

A classic—the Vari*Lite VL500. This tungsten color wash fixture is known for the distinctive jet-turbine fins. (It is also available with an arc lamp as the VL500A.)

(Courtesy Vari*Lite.)

known for its unique twin beam effect, in which the beam is split into two discrete hard-edged beams with variable control over the deviation and rotation speed.

The Cyberlight is probably the best-known moving-mirror style fixture (Figure 11.16). Although the pan tilt range is smaller than a moving-yoke fixture, the light can produce a full array of effects, including a multi-image prism, split color, near photo-quality image projection, wave glass, and a mosaic color effect. The light comes out the end of the fixture and hits a moving mirror, which is panned and tilted by a high-resolution, microstepping motor capable of panning the beam smoothly 170° and tilting 110°. A side effect of a moving mirror is that gobos or projected images rotate when the light is panned, and it is much more difficult to program straight-line pans.

Of course, your budget is also going to be a factor when selecting lights for a job. Many of the lights mentioned here are top-of-the-line and relatively new fixtures, but you can get the full range of effects from older lights that cost a fraction as much. A moving-mirror fixture like the Cyberlight is much less expensive to begin with and, depending on the intended application, the range of pan and tilt may not even present a limitation.

Moving lights may seem like they can do anything, and for the most part, they can. However, to insure reliability and longevity, it is advisable to avoid leaving them running continuously without a rest. These lights contain lots of electronics—circuit boards and even microprocessors. Although the motors used are generally very strong and dependable, nonetheless parts can and will fail. A ballyhoo using a bunch of moving lights is a wonderful look, but leaving it running for hours at a time takes a toll. You say, “But they’re rock-and-roll lights! Moving is what they were created to do.”

FIGURE 11.16

The Cyberlight 2.0 (High End Systems) is an example of moving-mirror fixture, where the fixture is stationary and the beam is panned and tilted by a mirror. This allows faster beam movement and less torque on the rigging. They are also typically cheaper than moving-yoke lights.

(Courtesy High End Systems.)

This is true, but when have you gone to a rock show that lasted 12 or 16 hours, with the lights moving nonstop? If you're doing a gig that does require the lights to move continuously, make a pause cue and rest the lights whenever possible between takes. This is preventive maintenance, and the moving light tech will thank you for it.

Working with moving lights

Typically, when moving lights are added to the lighting package, a moving light technician is added as well. This is someone who knows all the details of how to unpack, rig, set up, lamp, repair, and troubleshoot these lights. If you do not have a "tech," you are left thumbing through the light's operating manual and making phone calls. For each light, you'll need to ascertain how to lock and unlock the pan and tilt, how to navigate the setup menus, how to address the light, and how to set all the other profile options for your particular application. The setup menu contains various user selectable parameters, such as what it will do when it loses the DMX512 signal, whether it will autostrike, and so on. Each moving light will typically require a couple dozen DMX512 channels. The number of channels varies from model to model. A particular light can be set in a variety of modes, and each mode may require a different number of channels. The programmer will always want moving lights addressed sequentially with no gaps in the addressing, so the programmer needs to specify what mode he or she wants the lights set to, and what address to give each light. Depending on the model, the light may need to have AC power before it can be addressed. Some models are equipped with an onboard battery that enables addressing without the need for AC. This is very convenient when you are rigging and you don't yet have power.

Once the light is powered and turned on at the switch, it can then be given the instruction to strike via the control console. At that point, it will strike and proceed to calibrate itself. This process takes several minutes. When calibration is complete, the light will "home"—go to its default home position. At this time, the light may be controlled from the console.

Moving lights can be quite heavy. Most require a couple people to lift. They have a lot of moving parts and sensitive electronics, so steps should be taken to minimize opportunity for them to get banged up in the process of rigging and wrapping. Ideally, the truss can be lowered on chain motors to a convenient working height and the road cases can be rolled right up to the truss for rigging. All the lights must be oriented the same way on the truss. Moving lights typically clamp to the pipe or truss using two couplers or claws. A variety of couplers exist that make this process easier than it is when using standard couplers. Two popular models are the Mega Claw (The Light Source) and the Tee Slot Coupler (City Theatrical) discussed in Chapter 4. Moving-yoke lights put a considerable amount of torque on the truss when they move. Once raised in place, the truss must be fixed in place or it will swing and wobble when the lights move.

When ordering the lights you will need to determine the following: what type of electrical service it takes (many are autoranging from 100 to 240 V, 50 or 60 Hz; others are 208 to 240 V only, and some are 120 V only); what type of connector is on the power cord (typically either L6-20 or L6-30, but a small unit may use Edison); and whether the XLR connectors are 3- or 5-pin. Ideally, the distribution equipment that provides the circuit protection for the individual lights is located on ground level along with the control console. This makes it easy for the programmer to reboot the light if it develops a bug. To that end, the circuit breakers should be labeled with the fixture number so that you know which switch to reset. The distribution will be in large rolling racks with rows of socopex outputs (Figure 11.17). It is usually most convenient to run Socapex cable from the distribution box

FIGURE 11.17

Distribution rack for moving lights.

(Courtesy AC Power Distribution, Inc.)

to the lights, and then break-out to female fixture connectors, to connect the lights. It is important to color code the Socopex cable when working with more than one voltage. You may be working with 120, 208 V, and dimmer power all fed through different Socapex cables. Generally, yellow is the established color to denote 208 V power, and white or gray for 110 V, but people often use their own system of colors. You might choose to use red for 110 V nondim circuits, blue to denote dimmer circuits, and black for 208 V non-dim circuits. Color-coding the cable is essential to protect equipment, and very helpful when troubleshooting.

Remote pan and tilt for conventional lights

For conventional lighting situations, it is sometimes very helpful to have the ability to pan and tilt a light remotely, but using a moving light for this would be overkill. A number of manufacturers make DMX512-controlled motorized yokes for conventional fixtures such as a Source Four ellipsoidal spotlight (see Chapter 3). The Source Four can also be fitted with a moving mirror attachment. These are relatively inexpensive accessories that can offer real-time savings.

It is often the very large heads that we would like to be able to control remotely—when lights are attached to an aerial lift boom arm (Condor), for example. The ARRI MaxMover (Figure 11.18) is a large-capacity remote-controlled stirrup that can be adjusted in width and adapted for most large lights, including ARRI HMIs from 6 up to 24 kW (including 12ks by a couple other manufacturers as well), 12k and 24k ARRI tungsten heads, and even the 12-light Maxi-Brute.

To mount the light, the light's existing yoke is removed, adaptor plates are attached to the head, and the remote stirrup is adjusted to fit right to the adaptor plates. The maximum load is 176 lbs. The MaxMover Provides pan, tilt, and focus (flood/spot) control from either an analog controller (standard) that comes with a 160-ft cable, or a DMX converter (optional) that may connected using a cable or operated wirelessly. The analog controller provides joystick-type pan and tilt knobs and pushbuttons

FIGURE 11.18

ARRI MaxMover.

(Courtesy ARRI Lighting.)

for focus. An LED display shows when the flood/spot mechanism has hit its (software) stop. The analog control does not provide ballast control. There are a couple of different DMX512 converters that can be used. The "basic" DMX setup replicates the controls of the analog control using three channels to control pan, tilt and focus. Pan and tilt operate like a joystick, with 50% being the zero movement position. It is meant for manual control using any simple dimmer board. The more advanced method, Fully Programmable or "FP," uses eight channels, has 16 bit resolution, and employs separate channels for pan speed and tilt speed. It is designed to be triggered by a light cue in the same manner as moving lights. A moving light console works most easily with the FP DMX option.

The MaxMover comes with operating instructions that the user should definitely read. There are a number of things one needs to be aware of—for example, you should not plug in cables when the power is on. There is a specific procedure for mounting, balancing, and calibrating a light to the MaxMover.

The MaxMover can operate either overslung or underslung. A good way to rig to a condor basket is by attaching a short length of truss or pipe to the underside of the basket. This truss is centered under the basket so that it avoids the kinds of out-of-center load problem posed by mounting a light on the railing. The remote head can be underslung from the truss. This placement of the light has another advantage over placing it in the basket; the light can be placed closer to the top frame edge of the camera's shot. (When a light is mounted above the basket, the Condor arm itself comes into the shot while the light is still 8-10 ft above the frame.) Figure 11.19 shows LRX robotic lights underslung from a short piece of truss. (*Note*: some studios do not permit underslung lights when the operator will be in the basket. Safety authorities feel that there is no safe way for the operator to get into and out of the basket when the basket cannot be brought down to ground level. At this writing, a ladder is not considered a safe solution.)

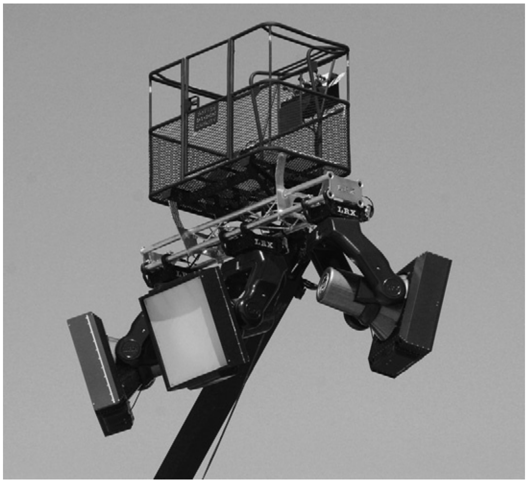


FIGURE 11.19

LRX robotic lights.

(Reproduced by permission of Brian Dwight, LRX, LLC.)

Media servers and video projectors for lighting effects

Motion graphics and video playback have become staples of broadcasting, theater, dance, concerts, and corporate events. Figure 11.20 shows a concert with live video being displayed on an enormous scale. In recent years, media servers have been designed to be controlled directly using a lighting control console and a common control protocol such as DMX512 or MIDI. A media server is a computer with ample graphics and processing power, storage, and RAM, which uses software developed specifically to store, play back, and manipulate digital media content (video, motion graphics, photographs). As a result of the trend by manufacturers to treat a media server as a lighting device, programming them has become the console programmer's responsibility.

A media server is used in conjunction with a video projector, digital lighting device, or LED display. Media servers provide the ability to combine and layer multiple images. The images may be manipulated and distorted in various ways. Some of these are practical; others are for effect. These include zoom, focus, color balance, and keystone correction (correcting distortion caused by the projector being positioned off-angle to the projection screen). Manipulation includes fades and dissolves between layers, color distortion, scaling and positioning, orientation, slow motion, soft edge, blending, and more.

FIGURE 11.20

An enormous screen (180 ft wide, 450 m^2 total) backed Coldplay for their 2009/2010 stadium tour called "Viva." The screen is a 30 mm spider of LEDs sourced from XL Video Worldwide. The screen is curved in both aspects. Control was via a Catalyst media server (High End Systems), triggered via an MA Lighting console. The screen enabled the lighting designer to get away from the standard square wall configuration and produce an immersive "eye."

(Courtesy Paul Normandale.)

FIGURE 11.21

The DL-3 is a projector with a moving light yoke and a media server built in.

(Courtesy High End Systems.).

Each layer of video may require 40 or more DMX512 channels. Media servers such as Catalyst (by Richard Bleasdale), Axon (High End Systems), M-box (PRG), Pandora Box (Coolux), and Hippotizer (Green Hippo, Ltd.) can provide eight or more layers. The channel count for running a media server can easily get into hundreds of channels. The DL-3 (from High End Systems; see Figure 11.21) is a media server built into the base of a projector, which has a moving-light yoke. With a unit like this, the projector can be panned and tilted remotely. The DL-3 has a more limited number of layers than stand-alone servers, but it simplifies the setup by containing everything in one automated unit.

The graphics files for the source material can be JPEG, TIFF, bitmap (BMP), or video such as MPEG2, AVI, or QuickTime (MOV). Accordingly, the source material can itself be manipulated using programs such as Adobe Photoshop, Adobe Illustrator, Adobe After Effects, and Apple Final Cut Pro. The creation of the source material is a shared responsibility. In cases where the source material is essentially a technical matter, it may be done by the programmer. When images possess more specific design elements the material is typically created or sourced by the art department.

In addition to projecting on a screen, media servers are used in motion-picture work to create various kinds of effects such as projecting repeatable images on an actor's face, creating a wall of rain, creating water reflections, creating reactive lighting effects, and so on.

Pixel-mapping systems

Another way to create a large-scale video display is mapping the images' pixels onto a large array of RGB LEDs. Each LED acts as a pixel in a large image. The LEDs themselves may be in linear tubes

FIGURE 11.22

This massive 750 m^2 spiral-shaped video stage was constructed for Marco Borsato's *Wit Licht* (*White Light*) concert in Holland using the Helix PI and STEALTH systems.

(Courtesy Element Labs, Inc.)

(such as Element Labs Versa TUBEs), tiles (such as Vera Tiles), or strings (Helix), which can be arranged as a flat screen or wall, or built around architecture, designed into graphic shapes, or put in any arrangement needed. As is dramatically illustrated in Figure 11.22, we're no longer confined to a rectangular surface for video.

We will use the Versa TUBE (Figure 11.23) as an example in this section. However, pixel mapping can be applied to any number of different lighting devices, including conventional light fixtures (albeit via intensity only).

FIGURE 11.23

Versa TUBEs can be arranged in rows to create a video wall, or designed into the set, or used to create reactive lighting. A High Definition Versa TUBE provides 36 pixels per meter. A Standard Definition Versa TUBE contains 16 pixels per meter. The tubes are available in lengths of 0.5 m (~20 in.), 1 m (~40 in.), and 2 m (~79 in.).

(Courtesy Element Labs, Inc.)

The Versa TUBE system is set up by first arranging the LED tubes on the set as desired. They are connected by separate data and power cables. Using a computer running pixel-mapping software called RasterMAPPER, the user maps out the way that each LED element exists in space. From this map, the software determines how it will address the individual LEDs. The Versa system offers a couple of different possibilities for sending the images to the LED tubes, depending on the requirements of the production. To display streaming video, the video signal is sent from a media server to a Versa drive unit having a DVI (Digital Video Interface) input. The driver unit uses the mapping information to translate the video signal into color and brightness information for each of the LEDs and sends the data to the LED array using a serial data cable (6-pin XLR) daisy chain.

When video images are not called for, a simpler system can be used to send animated graphics files. This system does not require a media server or a drive unit with DVI. Instead, the user imports images (such as AVIs or BMPs) into a computer and manipulates them as needed for display. Again, RasterMAPPER is used to map out the LED array. The map and the media files are output as CFF files, loaded into a Compact Flash card (CF), and loaded into a simpler drive device for playback. The drive device is controlled via DMX512 (or optional hand controller), so the playback, sequencing, and other manipulation of images can be written as lighting cues on a control console. This simpler system reduces the number of DMX512 channels from 40 or more for a media server to 6 for the CF Versa drive device. As many as 253 user-defined patterns (plus two factory defaults) can be played backward or forward, looped in various ways, and frozen at any point. The brightness, color balance, and resolution are also controlled via DMX512.

Pixel mapping has been used for various kinds of effects in motion pictures—to give an example, an ascending pattern of white and black gives the effect of an elevator descending (*Star Trek*). This works both as an on-camera effect and as a source of reactive lighting on the actors. Given the flexibility of lighting systems like these, and the level of control provided by the pixel-mapping technology, there are endless possibilities for on-camera and reactive effects using such a system.

LIGHT PLOTS

A *light plot* is a drawing showing where the lights are to be placed around the set. For film and television work, light plots are often created when a significant amount of equipment needs to be rigged in advance of actual shooting (Figure 11.24). A professional light plot is typically drafted using computer-aided drawing software (CAD), but it may also be drafted by hand on large sheets of velum using a T-square, a lighting template, and drafting pencils, or even hand-drawn on a regular sheet of paper. A CAD-based lighting program like Vectorworks Spotlight effectively streamlines the work of the entire department by providing plots, maps, charts, inventory lists, and hookup instructions that are accurate and easy to read.

Light plots may be created in different ways depending on their primary function. A light plot serves four important purposes:

- The light plot is a drawing board for designing the lighting. It establishes the necessary lights, rigging positions, and control required.
- The light plot is a blueprint with all the specifications needed for ordering and installing the lighting equipment.

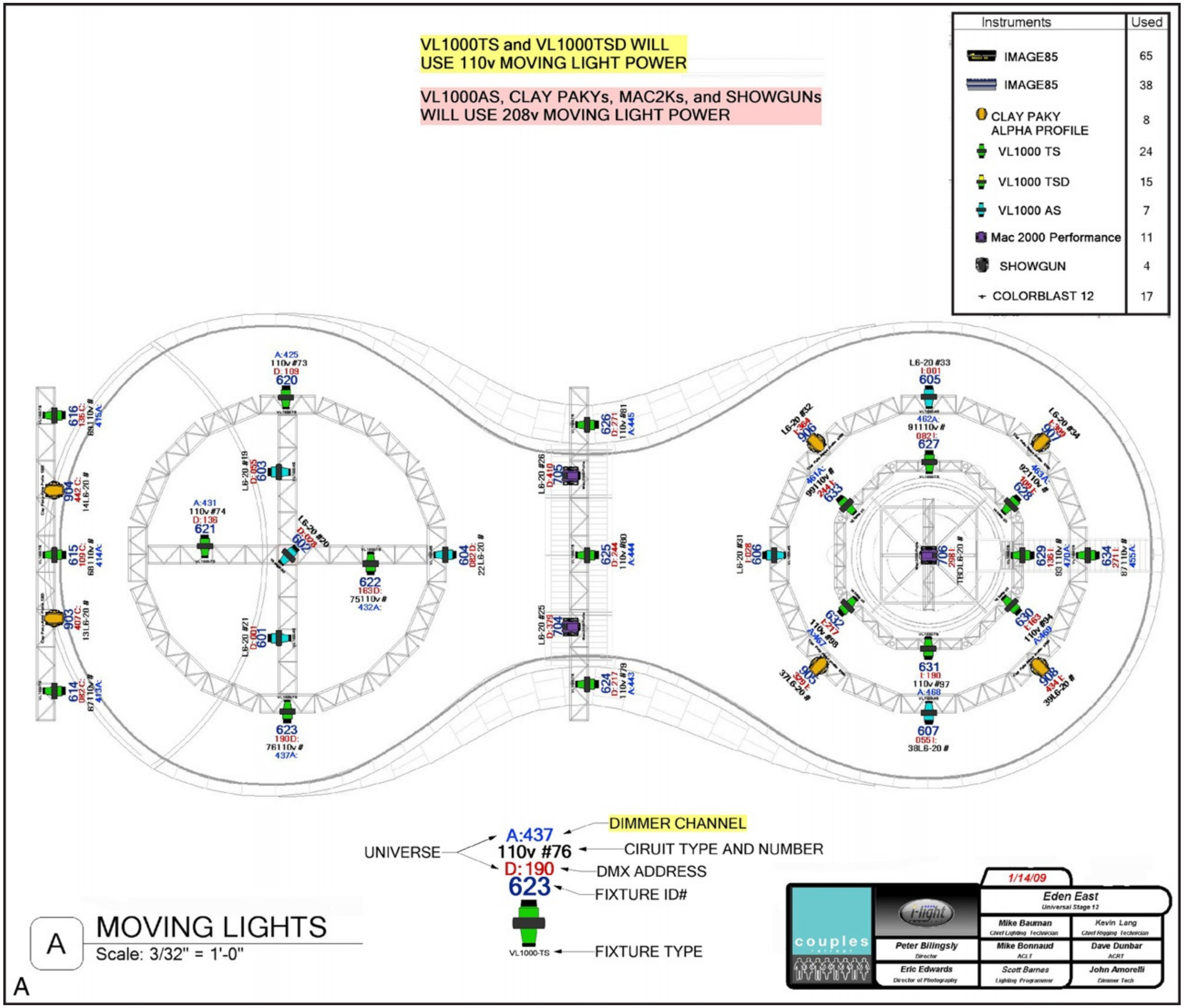


FIGURE 11.24

(A) Reproduced here is a black and white, reduced version of part of one layer of a large, color light plot drafted for a major motion picture. This layer is dedicated to the placement and hook up of the moving lights. Also shown on the plot are the associated truss positions, the green beds, and an outline of the set.

Continued

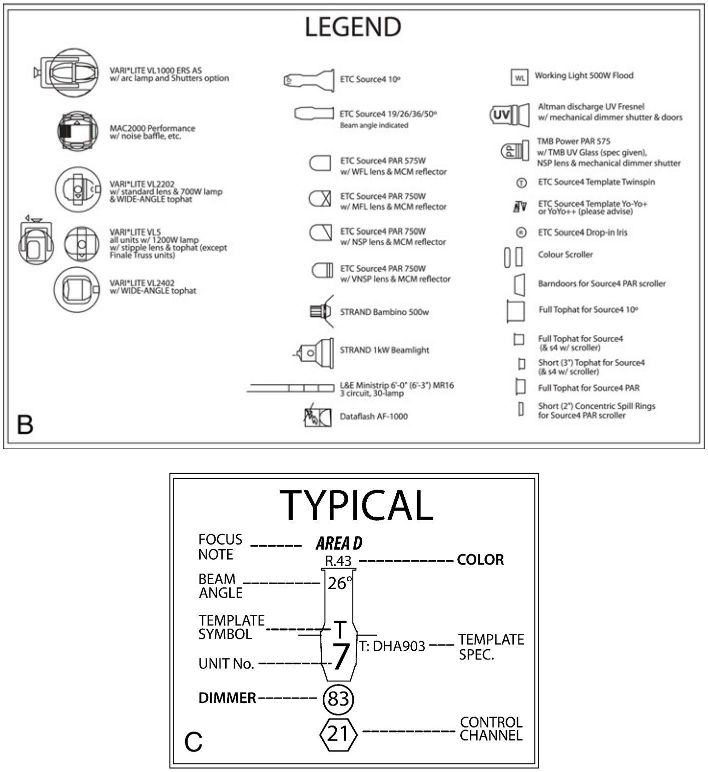


FIGURE 11.24—CONT'D

Other layers not shown here include those dedicated to: 1) fluorescent lights, 2) 20ks, 3) Soco power provided above the set, 4) space lights, and so on. The key in the upper right corner lists the instrument symbols used (which are color-coded on the original plot). A title block in the lower right corner identifies the show, the set and associated personnel. On this plot the scale and layer identification are provided in the lower left. A key that explains how each fixture is labeled for control is provided center bottom. This is sometimes included as part of the key, but here it is separated out for emphasis, because a custom scheme is used. Courtesy Scott Barnes. (B) The legend lists the lights used on the plot. One of the many ways Vectorworks Spotlight automates drafting is to automatically create a legend of all the instruments currently in use on the plot as shown here. (C) Information placed around each light follows a standard format that is taken from theatrical drafting and is commonly used in all lighting design. B and C Courtesy Vectorworks.

- The light plot is a roadmap that identifies each unit, each pipe or truss, and each circuit—information that will be needed during production. The gaffer will often carry a reduced-size laminated sheet on a lanyard around his neck in order to be able to call out fixture numbers to the dimmer board operator.
- The light plot is a record of lighting positions and notes that are kept so that each lighting setup can be recreated at a later point in the production schedule, or in the event of reshoots.

A light plot provides the basis for visualizer software. WYSIWYG has built-in visualizer software. Vectorworks has limited 3D capability, but is commonly used in conjunction with ESP Vision for rendering and previsualization (previz).

A discussion of the techniques of drafting and the use of CAD software is beyond the scope of this book. Helpful information and links can be found on the *Set Lighting Technician's Handbook* Web site.

LIGHTING WITH PREVISUALIZATION SOFTWARE

Figure 11.25 illustrates a programmer's full suite of computer-based tools, including the ability to actually render the lighting effect on the computer before any real lights are hung. Lighting previz software has sprung from the rock-and-roll/event side of entertainment. This software is designed to accurately render the look and features of every light fixture on a virtual set. For example, it can render multifaceted attributes like moving lights, moving gobos, color mixing, and so on with photorealism. A number of previz systems are available, including ESP Vision, WYSIWYG, Vari-Lite, and Capture Polar (used in ETC's software, among others).

You begin with a 3D model of the set built with AutoCAD or similar software. On top of this, you can build or import a light plot (such as a DWG file from Vectorworks or a MAX file from Studio Max). ESP Vision receives control data from a networked lighting console, and renders the lighting in real time, just as if it were happening live. You can place a "DMX camera" anywhere in the set and see exactly how the lighting would appear from that perspective. You can move lights

FIGURE 11.25

The toolset available to a lighting programmer: the large monitors display Vectorworks Spotlight (CAD light plot), and ESP Vision (previsualization software rendering the light cues). The light cues are run by the Wholehog lighting console (High End Systems). If video or graphic projections are also part of the performance, they can be processed in a media server that is also controlled by the console and displayed by ESP Vision.

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around, try different fixtures, create any number of different looks, preview lighting effects, plot exactly where fixtures should be placed, see where the shadows fall, and anticipate problems. You can create stills to be distributed or used for future reference. Any video elements within the scene also can be played in real time.

When large numbers of moving lights need to be programmed for a sequence, previz software allows the programmer to do this work well ahead of time and share the result with the DP and gaffer. There are many circumstances under which it may be extremely expensive or logistically impossible to afford the programmer sufficient time to do this programming "live" once the rig is up and running. In these circumstances, it is essential to have a way to program the lighting cues from a console and see the effect from any desired angle on a monitor. This work can be done weeks ahead of filming, leaving plenty of time to make changes and perfect the lighting cues. This provides the producer with cost savings and efficiency. Rock-and-roll designers using this software have been creating their lighting in a virtual world for some years now. This saves concert producers weeks of expensive rehearsal time in a real space, with a real crew, with real lights burning up real electricity. The same is true in motion-picture work.

Lighting software is different than storyboard previz software. Storyboard software has been in use for many years to create very accurate computer-generated storyboards. This software can output the exact lens, dolly configuration, height, and position of the camera and positions of the actors down to the millimeter. However, this type of previz does not typically involve lighting. Many DPs have voiced the feeling that—valuable as this software is—it removes the DP from the shot selection process. It predetermines too many of the choices that are the DP's tools and his craft. Shot selection and lighting go hand in hand. It can put the DP in a very difficult situation to make decisions about one without considering the other. Perhaps as lighting previsualization software continues to develop it will enable the DP to once again be intimately involved in the previsualization of both shot selection and lighting.

CHAPTER

Electricity

12

A real understanding of electricity enables the technician to troubleshoot intelligently, and is an essential part of set safety—for you, and for all those you work with. In this chapter, we start with the principles of how electricity works. We want to build a mental picture of how electrical forces behave; how current, voltage, power, and resistance are related; and how these relationships translate to our daily work. We need to understand the parts that make up a safe circuit—how switches, overcurrent protection, and grounding help keep a system safe. We'll discuss single-phase and three-phase alternating current (AC) power systems, and their associated voltage configurations. Woven throughout this conversation are references to the National Electrical Code (NEC) and other rules and guidelines. A more complete breakdown of rules of the NEC that are applicable in our work is available on the *Set Lighting Technician's Handbook* Web site. The next few chapters focus on the equipment and techniques that we use for electrical distribution and rigging, electrical problems, and the various types of power sources. Before we get to that, let's take a look at the fundamentals of electricity and electrical power circuits.

THE FUNDAMENTALS OF ELECTRICITY AND ELECTRICAL EQUATIONS

Electricity is the flow of electrons through a conductor. Electrons are forced into motion though a conductor when a power source is applied. As you know, a direct current (DC) battery provides two terminals to power an electrical device, such as a light; one terminal has a positive charge (+), the other has a negative charge (−). The amount of difference between their states represents the potential to do work. It is therefore referred to as the *potential* or *potential difference*. The greater the potential difference, the greater the force with which electrons are made to flow. When a light fixture is connected to the battery terminals, the wires and the lamp provide a path for electrons to flow from the negative terminal to the positive terminal of the battery. The chemical reaction taking place within the battery maintains the potential difference, which forces electrons to flow *continuously* through the circuit.

The flow of electricity and the electrical properties of components in a circuit are quantified by four basic units of electrical measure:

Set Lighting Technician's Handbook, 4e. DOI: 10.1016/B978-0-240-81075-1.00012-X

Unit	Description	Variable (used in equations)	Abbreviation (used to identify values)
Volts	Electromotive force, potential difference	*E*	V (volts)
Amperes	Current	*I*	A (amps)
Watts	Power output	*P* or *W*	W (watts)
Ohms	Resistance	*R*	Ω (ohms)

Volts (electromotive force)

The potential difference is the *electromotive force* or *voltage*. It is measured in volts (V). A flashlight operates on 1.5 V, a car battery at 12 V, and a wall socket at 120 V. Voltage is the force with which current is pushed through a resistance. When we measure voltage with a voltmeter, we read the difference in voltage potential between two points in a circuit (between the hot wire and the neutral wire, for example).

E is the variable used to represent voltage (E for electromotive force) in equations.

Amperes (current)

The flow of electrons is called *current*. In an electrical circuit, the volume of electricity per second (rate of flow) of electricity is measured in *amperes*, or *amps* for short (one coulomb per second equals one ampere). Amp is abbreviated A (as in a 1000 W light pulls 8.3 A). In practical terms, amps represent the amount of current being pushed through the load (lights) by the voltage of the power source. The amperage of a circuit is important to electricians, because cable, connectors, and other distribution equipment must be large enough to carry the amperage required by the load. If cables are too small, they heat up, which causes a number of problems, including the potential to start a fire. Every element in an electrical distribution system, from the generator to the lamps, has to be sized to handle the amperage (current).

By convention, the letter *I* is used to represent current when it is an unknown quantity in electrical equations (for example, a 10,000 W light pulls a current of 83.3 amps so $I = 83.3$ A).

Watts (power)

Wattage can be thought of as total power *output*; in the case of lighting fixtures, wattage is the amount of total output (light and heat). A high-wattage bulb is brighter than a lower wattage one. The total amount of electrical power being delivered at any one moment is measured in watts, abbreviated W. The wattage is the product of the amperage (amount of current) and the voltage (electromotive force). Wattage is the measure of the amount of work being done in any one instant. It is the same idea as horsepower; in fact, 746 W = 1 hp.

The letter *P* is conventionally used as a variable to represent wattage (power) in equations. However, *W* is also sometimes used.

Most of the time lights are referred to in kilowatts, meaning thousand-watts, abbreviated kW. A baby is a 1000 W light or 1 kW. Thus, the common terminology: 1k, 2k, 5k, and so on.

For the purpose of billing, the power company's meter counts the electricity consumed in kilowatt-hours (kWh). The wattage used at any given time is reflected in the speed at which the disk in the meter turns. Kilowatt-hours measure the total amount of electrical power consumed over a given amount of time: the rate at which power is consumed in a given moment, measured in kilowatts, multiplied by the hours that power is consumed at that rate.

The power equation

Watts are mathematically related to volts and amps as follows:

$$P = IE \quad \text{or} \quad \text{watts} = \text{volts} \times \text{amps}$$

An easy way to remember the power equation is to think of West Virginia ($W = VA$), or *easy as PIE*.

From this, we can see that both voltage and current (amperage) contribute to the total output (wattage). Consider two 60 W bulbs, a household bulb and a car headlight. The household bulb runs on 120 V and draws a current of 0.5 A. The car headlight uses a 12 V battery but draws current at a rate of 5 A. The total power consumed and the total amount of light emitted are the same for the 60 W household bulb and the 60 W car headlight:

$$\text{Household bulb}: 120\ \text{V} \times 0.5\ \text{A} = 60\ \text{W}$$

$$\text{Car headlight}: 12\ \text{V} \times 5\ \text{A} = 60\ \text{W}$$

To make the same point another way, in Great Britain the standard voltage is 240 V.[1] Consider what this means for a 10k lamp.

$$120\ \text{V} \times 83.3\ \text{A} = 10{,}000\ \text{W}$$

$$240\ \text{V} \times 41.67\ \text{A} = 10{,}000\ \text{W}$$

Note the amperage of the 240 V lamp is half of that of the 120 V lamp. The two lamps are the same brightness regardless of voltage. So a 10k is a 10k the whole world over, but in the United Kingdom, a 10k has half the amperage, and can use a much smaller cable.

Take a look at Table 12.1. The table lists the amperage of a variety of wattage lights for various voltage systems. Note the various permutations of the relationships between voltage, amperage, and wattage. Note that a 100 W lamp operating at 12 V pulls the same amperage as a 1000 W lamp at 120 V or a 2000 W lamp operating on a 240 V system.

The power equation can be stated three different ways:

$$P = IE \quad \text{or} \quad \text{watts} = \text{volts} \times \text{amps}$$

$$E = \frac{P}{I} \quad \text{or} \quad \text{volts} = \frac{\text{watts}}{\text{amps}}$$

[1]This standard is changing to 230 V as used in most of the rest of the European Union. But for this example, 240 V is a nice number to use to show the relationship of watts to volts and amps.

Table 12.1 Amperage of lights with various voltage systems

	System voltage					
Lamp wattage	*240 V*	*230 V*	*208 V*	*120 V*	*30 V*	*12 V*
100 W	0.4 A	0.4 A	0.5 A	0.8 A	3.3 A	8.3 A
200 W	0.8 A	0.9 A	1.0 A	1.7 A	6.7 A	16.7 A
300 W	1.3 A	1.3 A	1.4 A	2.5 A	10.0 A	25.0 A
400 W	1.7 A	1.7 A	1.9 A	3.3 A	13.3 A	33.3 A
500 W	2.1 A	2.2 A	2.4 A	4.2 A	16.7 A	41.7 A
650 W	2.7 A	2.8 A	3.1 A	5.4 A	21.7 A	54.2 A
750 W	3.1 A	3.3 A	3.6 A	6.3 A	25.0 A	62.5 A
1000 W	4.2 A	4.3 A	4.8 A	8.3 A	33.3 A	83.3 A
1500 W	6.3 A	6.5 A	7.2 A	12.5 A		
2000 W	8.3 A	8.7 A	9.6 A	16.7 A		
3000 W	12.5 A	13.0 A	14.4 A	25.0 A		
4000 W	16.7 A	17.4 A	19.2 A	33.3 A		
5000 W	20.8 A	21.7 A	24.0 A	41.7 A		
6000 W	25.0 A	26.1 A	28.8 A	50.0 A		
8000 W	33.3 A	34.8 A	38.5 A	66.7 A		
9000 W	37.5 A	39.1 A	43.3 A	75.0 A		
10,000 W	41.7 A	43.5 A	48.1 A	83.3 A		
12,000 W	50.0 A	52.2 A	57.7 A	100.0 A		
20,000 W	83.3 A	87.0 A	96.2 A			

$$I = \frac{P}{E} \quad \text{or} \quad \text{amps} = \frac{\text{watts}}{\text{volts}}$$

Calculating the amperage of lights

Actual amps and paper amps

We frequently use the power equation to calculate the current pulled by a given load ($I = P/E$). Remember, the amount of *current* needed determines all the major parameters of our work when installing a distribution system: the size of the cables, the size of the power plant, the balance of load between phases, and the amount of line loss.

To calculate the amperage pulled by a given light fixture, divide the lamp's wattage by the line voltage. For example, for a 1000 W light operating at 120 V, we make the following calculation:

$$I = \frac{P}{E} \quad \text{or} \quad \text{amps} = \frac{\text{watts}}{\text{volts}}$$

$$\frac{1000\ \text{W}}{120\ \text{V}} = 8.3\ \text{A}$$

Table 12.1 gives the current for all the most common wattages.

Table 12.2 Paper method example

Wattage	Paper amps	Real amps
300	3	2.5
500	5	4.2
1000	10	8.3
2000	20	16.7
4000	40	33.3
5000	50	41.7
10,000	100	83.3
Total	**228**	**190 (rounded to the nearest amp)**

Paper amps

A quick method for calculating amperage is to divide the wattage by 100, an easy calculation to do in your head. Dividing by 100 overestimates the amperage, which introduces a safety margin (16.6% per light). This is known as the *paper method* of calculating the total load. Paper quantities are 1.2 times the real amperage; that is, real current is 83% of the paper value.

To calculate the total current flowing through a cable, simply add up the amps pulled by each light. In Table 12.2, note how much easier it is to add the paper column than the real column.

Electricians have used paper amps since the old days, because it simplifies everything. It simplifies the arithmetic, and it also accounts (to some extent) for necessary derating of equipment. The electrical code stipulates that for a load in continuous use, the overcurrent protection must be derated to 80%. We often need to run lights for long unspecified periods of time, so using paper amps derates the load by 83.3% automatically. Similarly, generators should not be run continuously at more than 80% of capacity, as this causes undue wear. When running a generator, we also need to maintain "head room" to allow for momentary current surges (especially HMI ignition). Not doing so can overload the power plant, resulting in the generator shutting down or tripping the main breaker. You can see why electricians have long used paper loads. They simply don't worry about derating, and live in a world where the math is easy. It is not an exact way of making load calculations, but it is quick and easy, and most often near enough.

Resistance and Ohm's law

So far we have a mental picture of a lamp operating at the standard 120 V, drawing current (amps) to generate a particular wattage output. However, this is an incomplete picture of the forces acting on a circuit. What prevents an ambitious 60 W lightbulb from drawing more current and becoming a 600 W lightbulb? The force we are missing is resistance. Understanding how resistance relates to power and current gives us a much clearer picture of the forces at work in a circuit.

Resistance is the opposition to the flow of current created by the load (the fixtures plugged into the circuit) and by the resistance of the wires themselves. Resistance is measured in ohms, abbreviated as the Greek letter omega (Ω). Example: A 120 V 2 kW light has a resistance

of 7.20 Ω. R is used to denote resistance when it is an unknown value in electrical equations ($R = 7.20$ Ω). The resistance of a particular lamp filament, once it is running, can be considered a constant, determined by its physical properties and construction. The resistance of the filament limits the current that can be pushed through it by a particular voltage and, therefore, determines its ultimate output in watts.

Ohm's law

Ohm's law states the relationship of resistance to voltage and amperage. It can be stated three ways:

$$I = \frac{E}{R} \quad \text{or} \quad \text{amps} = \frac{\text{volts}}{\text{resistance}}$$

$$R = \frac{E}{I} \quad \text{or} \quad \text{resistance} = \frac{\text{volts}}{\text{amps}}$$

$$E = I \times R \quad \text{or} \quad \text{volts} = \text{amps} \times \text{resistance}$$

Figure 12.1 shows the formulas wheel that gives all the possible relationships between voltage, wattage, amperage, and resistance. Figure 12.2 shows an easy way to remember these relationships.

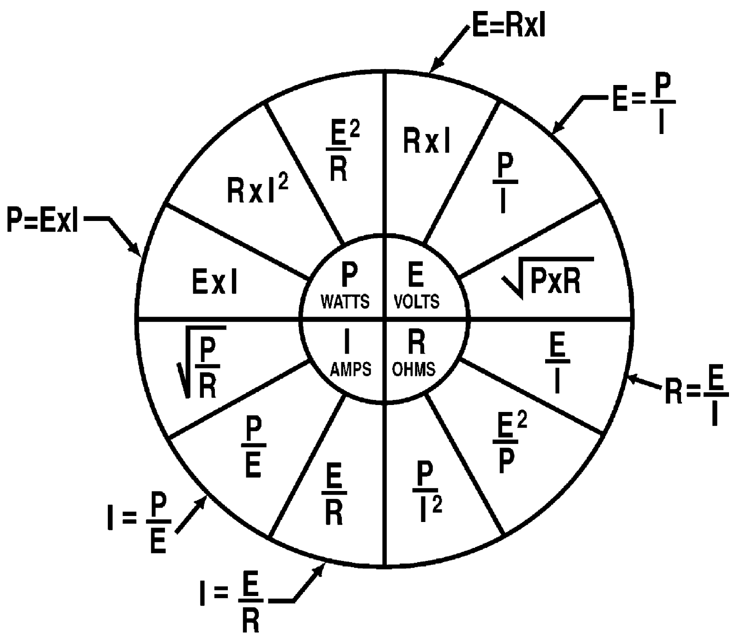

FIGURE 12.1

The formulas wheel gives every permutation of the relationships between voltage, amperage, wattage, and resistance.

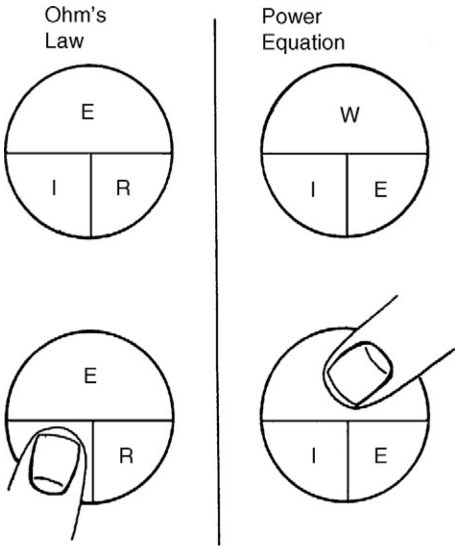

FIGURE 12.2

A simple way to remember the most common equations in Figure 12.1 is to use "magic circles." On either of the circles shown, cover the symbol you want to find with your finger. The relationship that remains is the formula. For example, to determine amperage (*I*) from a known resistance (*R*) and voltage (*E*), put your finger on the *I* and read *E* divided by *R*. To determine wattage (*W*) from amperage and voltage, put your finger over the *W* and read *I* times *E*.

Resistance of a light

Ohm's law, stated as $R = E/I$, can be used to calculate the resistance of a load (like a light fixture). The resistance of a particular load can be calculated by dividing its rated voltage by the amperage. For example, a 5k bulb (rated 5000 W at 120 V) pulls 41.67 A. The resistance of the lamp can be calculated as follows:

$$\frac{120\ \text{V}}{41.67\ \text{A}} = 2.88\ \Omega$$

Resistance of cable

Cables also have resistance. The resistance of a particular length of cable is equal to the voltage drop in the cable divided by the amperage running through it. If there is a 4 V drop in a length of cable carrying a 40 A load, the resistance of that length of cable is:

$$R = \frac{E}{I} \quad \text{or} \quad \text{ohms} = \frac{\text{volts}}{\text{amps}}$$

$$\frac{4\ \text{V}}{40\ \text{A}} = 0.1\ \Omega$$

Using Ohm's law

$I = E/R$ calculates the amperage drawn by a particular load, knowing the line voltage and the load's resistance. To see how this equation works, let's use it to illustrate the dramatic effect of line loss.

All conductors, such as cable, have resistance. In a long length of cable, the resistance causes a perceptible drop in voltage from source to load, because resistance turns some power into heat in the cables. This is known as *line loss*. Looking at $I = E/R$, we can see that if voltage decreases (due to line loss), the amperage also decreases. We can calculate that, if the voltage is reduced to 108 V, a 2000 W bulb (normally 16.6 A, 7.36 Ω) draws less current than it should. Using Ohm's law, we can calculate the actual current:

$$I = \frac{E}{R} \quad \text{or} \quad \frac{108\ \text{V}}{7.36\ \Omega} = 14.7\ \text{A}$$

The actual current is only 14.7 A, instead of 16.6 A. Now, using the power equation, we can calculate the actual power output of the 2000 W lamp:

$$W = I \times E \quad \text{or} \quad 108\ \text{V} \times 14.7\ \text{A} = 1584\ \text{W}$$

The output is sliced down to 1584 W.

The problem is compounded by the fact that a light operates at full efficiency only at its rated voltage. Operating at 108 V (90% of its rated power), the 2k in fact produces only about 68% of its normal light output. That's one wimpy 2k—a 32% loss of output caused by a 10% loss of voltage. Light output decreases geometrically with voltage.

Inrush current

A brief explanation of in-rush current will provide a further illustration of how resistance works in a circuit. We said a moment ago that the resistance of a lamp filament can be considered a constant. However if we are more precise about it, we should say the resistance is constant *at a given temperature*. Any metal has less resistance at a lower temperature; as temperature increases, so does resistance. With tungsten, this effect is very pronounced—when cold it has very little resistance but when heated it has very high resistance. As a result, from a cold start, tungsten lights have high in-rush current (25 times the nominal current) which lasts a couple milliseconds until the filament temperature increases, bringing the resistance up, and the current down to their nominal values. This is the reason that we use dimmers to bring up 20k lamps—to avoid slamming the (expensive) lamp filament with high inrush current. Once at operating temperature, however, resistance is constant.[2]

PARALLEL AND SERIES CIRCUITS

Several lamps can be connected in a single circuit in one of two ways: in parallel or in series (Figure 12.3). Lighting equipment is almost always connected in parallel; however, series circuits also become important to us in a number of ways, as you will see.

[2]In contrast, the resistance of copper changes very little with temperature.

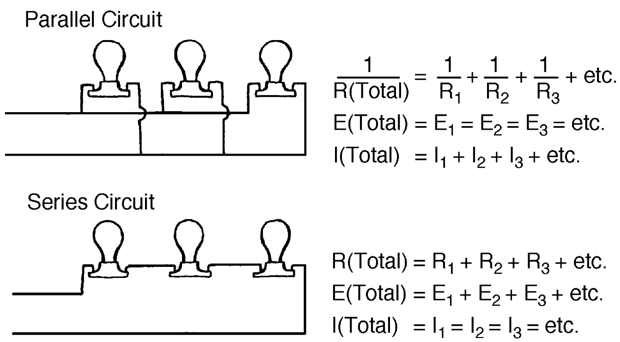

FIGURE 12.3

In a parallel circuit, voltage is constant everywhere in the circuit and the sum of the amperages of the fixtures equals the total amperage of the circuit. In a series circuit, amperage is constant everywhere in the circuit and the sum of the voltages of each fixture equals the voltage of the circuit.

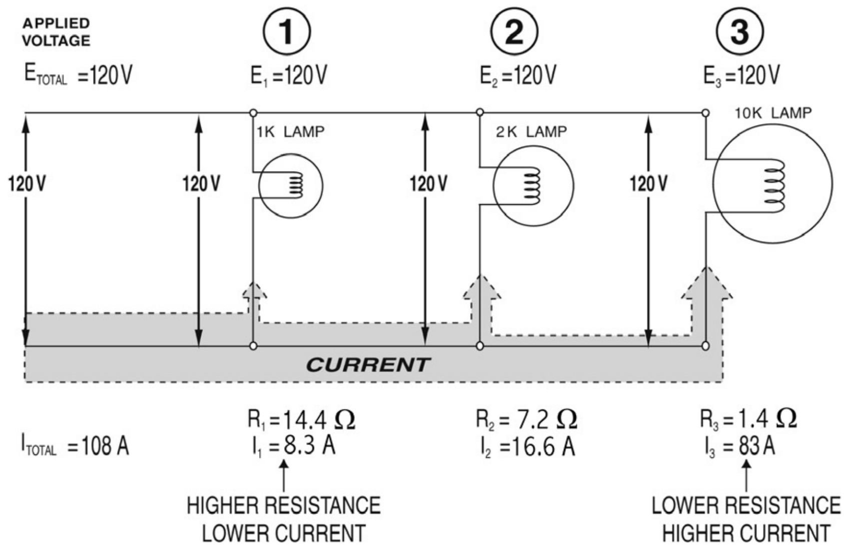

FIGURE 12.4

In a parallel circuit, the same voltage is applied to each load in the circuit. The current divides among paths in inverse proportion to the resistance present in each path.

In a *parallel* circuit (Figure 12.4), each load is connected across the full potential difference (voltage) of the power source. The total *voltage* is therefore the same as the voltage across each and every load on the circuit ($E_T = E_1 = E_2 = E_3$, etc.). Each of the loads provides a separate path for current to flow. The amount of current in each path depends on the resistance in that path. The sum of the amperages of the separate loads is equal to the total amperage of the whole circuit ($I_T = I_1 + I_2 + I_3$, etc.).

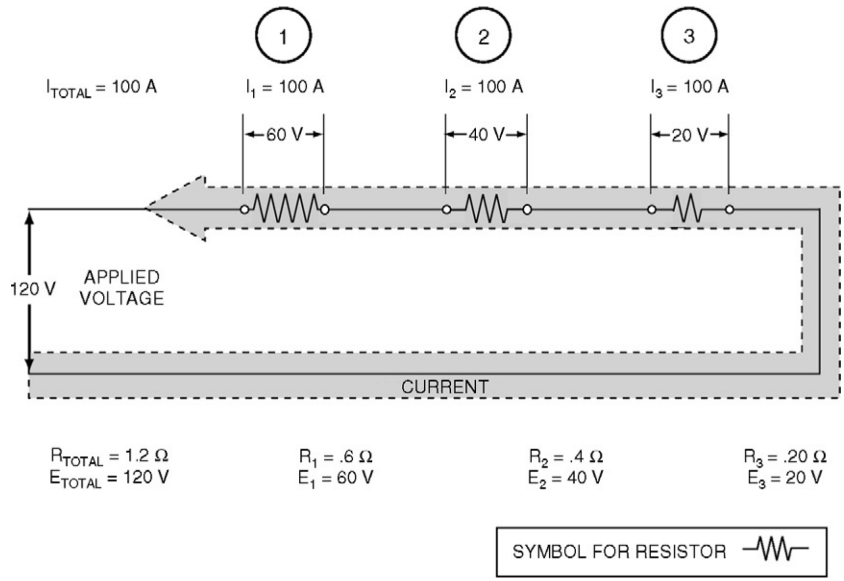

FIGURE 12.5

In a series circuit, the total current flows through every part of the circuit. The total voltage is divided among components in proportion to their resistance.

In a *series* circuit, the components are connected end to end (Figure 12.5). The current has only one path to complete the circuit and must pass through every component to complete the circuit back to the power source. (I use the general term "component" here. In our case, a component most likely is a load such as a light, but it might also be a battery or an electronic part such as a resistor.) The *amperage* is therefore the same throughout the circuit, found by calculating total current (I_T).

In a series circuit, the voltage divides among the components. The sum of the voltages across each component ($V_1 + V_2 + V_3$, etc.) equals the total voltage of the circuit (V_T). The voltage across each component depends on the resistance of that component.

In a series circuit, the total resistance of the circuit (R_T) equals the sum of the resistances of the separate components ($R_1 + R_2 + R_3$, etc.).

It is important to remember that in a series circuit, the total current of the circuit runs through every component. You cannot calculate the current of a single component knowing the wattage and voltage of that component as you can with a parallel circuit, unless the loads are all identical. The current running through each component depends on what other components are connected in the series circuit. Therefore, to calculate the current for any component you must calculate the total current (I_T). To find the total current, add the resistances of all the components. Then divide the circuit voltage (E_T) by the total resistance, R_T (using Ohm's law to find I_T):

$$\frac{E_T}{R_T} = I_T$$

If all the components in a series circuit have *exactly the same resistance*, then you can simply calculate the current of any individual component (e.g., $I_1 = P_1/E_1$) and the result will be the same as calculating I_T.

As you can see, in a series circuit, if there is a break in the circuit at any point (if one of the filaments blows, for example), the entire circuit is interrupted and none of the lights receive power.

To help show how voltage and current behave differently in a series circuit than in a parallel circuit, let's look at a simple example of series connected components: a battery pack. A 120 V battery pack consists of ten 12 V batteries connected in series: negative to positive, end to end (Figure 12.6). When connected in series, the total voltage of the pack is equal to the sum of the voltages of the individual batteries. If just two batteries were connected in series, the voltage would be 24 V (12 V + 12 V = 24 V).

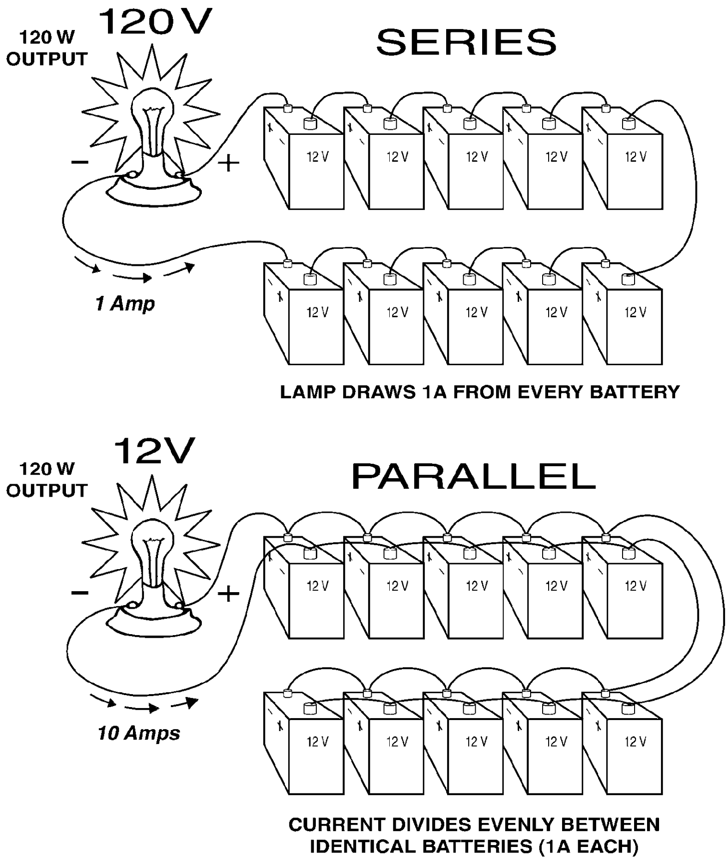

FIGURE 12.6

In the series circuit (top), the voltage across all ten batteries adds up to the total voltage of 120 V. If the lightbulb is a theoretical 120 W, 120 V bulb, the total current (1 A) travels though every part of the circuit. In a parallel circuit (bottom), the voltage is the same (12 V) at every point in the circuit—no matter how many batteries are used. The theoretical 120 W, 12 V lightbulb pulls 10 A, which divides among the 10 batteries (1 A each). Both lightbulbs have the same light output.

If five 12 V batteries were connected in series, the total voltage would be 60 V (12 V + 12 V + 12 V + 12 V + 12 V = 60 V). To get 120 V, therefore, you need ten 12 V batteries in series.

If the 10 series-connected batteries were connected to a 120 V lamp, you would complete a *series circuit*. As you know, the total current flows through every component (each of the batteries, and the 120 V lamp), because the series circuit provides only one path through the entire chain of batteries and the lamp. The current is therefore the same measured across any component in the circuit. In contrast, if any number of batteries were connected in parallel, the voltage would always remain 12 V. Increasing the number of batteries in parallel would increase the *current* available, or, to put it another way, the current drawn by the lamp would divide among the batteries.

To put it simply: voltage is the same across each component of a parallel circuit; current is the same across each component of a series circuit. Current divides among the multiple paths provided by a parallel circuit (in inverse proportion to the resistance in each path); voltage divides among multiple components connected in series (in proportion to the resistance across each component).

HOW NOT TO USE ELECTRICAL EQUATIONS

One has to be careful to apply Ohm's law and the power equation correctly. For example, consider what happens when you dim a 1000 W lamp using a variac (variable transformer). As the voltage is reduced from 100% to 50%, what happens to the current? If watts divided by volts always equals amps, then when the voltage goes to half, you might conclude that the amperage must double:

$$\frac{1000 \text{ watts}}{120 \text{ volts}} = 8.3\text{amps}$$

So,

$$\frac{1000 \text{ watts}}{60 \text{ volts}} = 16.7\text{amps}$$

However, this is not consistent with our experience. As you dim the light, it should not draw more current. The mistake we made was assuming that wattage is a constant. When you dim the light, wattage decreases. Despite the number that is stamped on the bulb, the output changes. The constant is the lamp's resistance.

$$I = \frac{E}{R}$$

For a 1000 W lamp, $R = 14$ ohms, so

$$I = \frac{60 \text{ V}}{14\ \Omega} \quad \text{or} \quad 4.3 \text{ A}$$

At 60 V, the 1k draws 4.3 A—and because watts = volts × amps,

$$60 \text{ V} \times 4.3 \text{ A} = 258 \text{ W}$$

That result is consistent with our experience.

To give a contrasting example, consider what would happen if you were to use a variac to power a 12 V, 100 W lamp. If you did not have a 12 V power supply, you could use the variac dimmer

and dial it down to 12 V. If you have 10 such lamps you would have 1000 W load. But could you use a 1000 W variac dimmer and hook them up with #12 wire? How would we figure the amperage? You might think that you calculate the amperage as follows:

$$\frac{1000\ \text{W}}{120\ \text{V}} = 8.3\ \text{A}$$

But this would be a pretty disastrous mistake (actually, you'd just blow the fuse in the variac). When you use the variac as a transformer set to 12 V, the 12 V lamps operate at full intensity. The total wattage really is 1000 W, but the total circuit voltage is only 12 V, not 120 V. If you'd turned on all 10 of those little lamps:

$$\frac{1000\ \text{watts}}{12\ \text{volts}} = 83\ \text{amps}$$

You would have been pulling 83 A. That's like hooking up a 10k to a 1k variac. Each of those 12 V lamps is drawing 8.3 A.

There is a way to connect all ten 12 V lamps to a 1k variac without any problem—put them in series. The voltage in a series circuit divides among the components of the circuit in proportion to the resistance of each component. In this case, all the bulbs have the same resistance, so the circuit voltage (120 V) would have divided evenly—12 V per light.

$$12 + 12 + 12 + 12 + 12 + 12 + 12 + 12 + 12 + 12 = 120\ \text{V}$$

Remember, current is the same every place in a series circuit, and it is equal to the total wattage divided by total voltage:

$$\frac{1000\ \text{W}}{120\ \text{V}} = 8.3\ \text{A}$$

The moral of this story is to be sure that you have properly identified which quantities are fixed and which depend on other variables. Understand what is going on in the circuit (drawing it helps) before choosing the equation to apply.

COMPONENTS OF A SAFE POWER CIRCUIT

The essential parts of a safe electrical circuit between the power source and the load are shown in Figure 12.7:

- Control device (such as a switch or dimmer)
- Overcurrent protection (a fuse or circuit breaker)
- Current carrying conductor cables (appropriate to handle the current)
- Equipment grounding conductor

Control devices and polarity

A circuit should not be considered complete without a control device. The control device is used to open and close the circuit. (A *closed* circuit forms a complete circle back to the power source. In an *open* circuit,

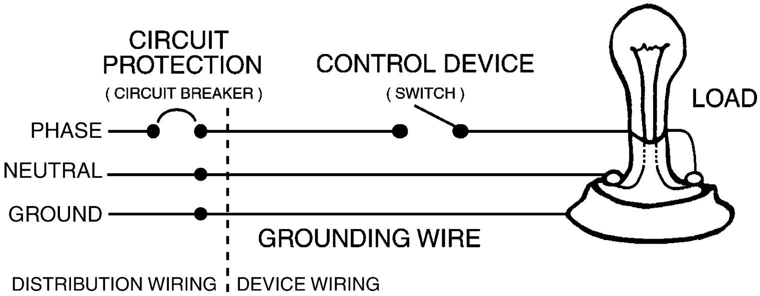

FIGURE 12.7

The components of a safe circuit: circuit protection, control device, appropriate conductors, and grounding wire.

the circle is interrupted by an open switch or lost connection.) Plugging or unplugging a cable is not a good way to close and open a circuit, except in an emergency.

Power switches are either single-pole or double-pole switches. A single-pole switch opens the circuit by interrupting the "hot" wire. A double-pole switch interrupts both wires (hot and neutral, or two "hot" wires in the case of 208 or 240 V loads). Most small lights up to 1k use a single-pole switch. Those 2k and higher use double-pole switches. With the smaller lights, it is critical that the connector provide proper polarity so that the hot wire is interrupted by the switch, not the neutral. If the polarity is reversed then an invisible hazard exists, by which in the event of a short in the fixture, the housing of the fixture could be energized, even though the light is switched off! This is the reason that all multipole connectors are polarized and grounded with the ground conductor making contact first when the connector is plugged. If you look at the design of the household Edison plug, for example the conductors are polarized (cannot be reversed), because one blade of the plug is wider than the other. The ground conductor mates first because it is longer than the flat blades of the hot and neutral conductors. A properly installed multipole connector makes it impossible to reverse the phase or energize a load without a ground. The same principle applies to the design of Stage Pin connectors (Bates), twist-lock connectors, and all other legal multipin connectors.

There are some important differences between AC and DC switches and circuit breakers. A property of DC is that when there is a narrow gap between contacts, the current arcs and begins to burn the contacts (the carbon arc light operates on this principle). Every time a switch is opened or closed, a short gap exists for an instant. If the current is allowed to arc each time the switch is opened or closed, it will burn away the contacts of the switch very quickly. To prevent the arc, DC switches and circuit breakers are spring-loaded so that the contacts snap together quickly.

The most common household switches, AC-only switches, do not require this feature and operate quietly, without a snap. Do not use AC-only switches or breakers with DC circuits. The letters AC appear after the rating on the switch.

AC/DC switches can be used with either AC or DC power. If AC does not appear on the rating of the switch, it is an AC/DC type. If an AC/DC switch is to be used to control an incandescent light, it must have a "T" (tungsten) rating (a slightly beefier switch is needed to handle the high initial inrush current drawn by a cold tungsten filament).

Overcurrent protection

An overcurrent device guards against the danger posed by either a short circuit or overcurrent situation. In a *short* circuit, a fault allows the "hot" wire to come in direct contact with neutral or ground or another phase wire, which shortcuts the path back to the power source, allowing current to flow directly across the power source from the outgoing wire to the return wire with only the resistance of the wires themselves to oppose the current. A short might be caused by damaged cable insulation, a crushed connector, a loose connection inside a light, or a foreign metal object coming in contact with both terminals somewhere in the circuit. Without resistance in the circuit, the current rises rapidly, creating an overcurrent situation. An *overcurrent* also results when too large a load is placed on a circuit.

From Ohm's law ($R = E/I$), you can see that the higher the amperage flowing through a fixture, the lower the resistance in the circuit; conversely, the lower the resistance of a fixture, the more amperage is allowed to flow. What happens if there is no resistance? If you create a dead short by touching the two wires together, the uninhibited current flow rapidly increases to the maximum available from the power source, which may be thousands of amps. The amperage in the circuit becomes extremely high—far beyond the amperage capacity of the cables. The wires heat up, burn, and melt (quite possibly setting the building on fire) or, if the amperage is high enough, can vaporize the cables in a matter of seconds. For this reason, every circuit is protected by an overcurrent protection device, a fuse or circuit breaker.

An overcurrent device cuts off power to the circuit if the current exceeds a specified limit. The amperage capacity of cables downstream of the overcurrent device is matched to the rating of the overcurrent device. Thus, circuit protection prevents the possibility of thermal meltdown of overloaded conductors.

A power distribution system employs a tiered system of circuit protection—large-capacity overcurrent protection for the feeder cables, low-capacity circuit protection for the larger branch circuits (to which the loads are connected), and small-capacity circuit protection for smaller loads. Why all these levels of circuit protection? The reason for the tiered system is twofold. First, of course, it would be undesirable to use only one large-capacity circuit breaker to protect a whole system for practical reasons. If a short happened in one light, the whole set would go dark. However, there is a second reason that is important for safety. Every conductor downstream of the overcurrent protection has impendence. A long length of small wire that is protected at a relatively high overcurrent threshold can create enough impedance that the overcurrent protection will not trip. Meanwhile the wire will overheat and melt, which poses a potential fire hazard, as well as a burn hazard and shock hazard for anyone who makes contact with the wire. This is also the reason that the ampacity of feeder cables is matched to the size of the overcurrent protection.

Circuit breakers and fuses

The most common type of circuit protection today is the circuit breaker. In our industry, we like to use *magnetic* breakers. A magnetic circuit breaker interrupts the circuit if there is an overcurrent or short circuit. *Thermal-magnetic* breakers are common in homes. These are sensitive to temperature as well, which is an important safety feature when the wires are buried inside walls. In set lighting, thermal-magnetic breakers tend to cause nuisance tripping.

A less-expensive alternative to a circuit breaker is a fuse. Most large fuses (100 A or more) are of the cartridge fuse type, which may be renewable (the end caps screw off and the broken strips

are replaced). Nonrenewable fuses tend to heat up less and are favored in situations where there is little chance of an overcurrent. Fuses may or may not have a time delay. A time-delay fuse is designed to allow for startup loads, which may briefly exceed the nominal current rating of a piece of equipment. This is the case with motors and with HMIs. Circuit breakers are designed to provide a time delay automatically.

As mentioned earlier, circuit breakers and fuses are installed to protect cable and equipment from thermal meltdown, but they are not designed to protect people from shock. The equipment grounding system we shall talk about shortly is one safeguard against electrical shock. When a shock hazard may exist, such as in wet locations, ground fault circuit interrupters (GFCI) must be used to protect against shock hazard from leakage current or equipment faults. GFCI equipment is covered in detail in Chapter 17.

The current-carrying capacity of cable

There are a number of factors that affect the amperage capacity of cables. An amperage capacity or *ampacity* is assigned to each type of cable in the NEC based on the wire gauge, type of insulation, and temperature rating of the insulation. This rating may also be required to be adjusted for the ambient temperature, the number of conductors in the cable, the length of time it is under load continuously, and the maximum temperature rating of the overcurrent protection to which it is connected. Let's begin with wire gage.

Wire gauge

Wire sizes are numbered using the American wire gauge (AWG) sizes shown in Figure 12.8. For wire sizes from 18 to 1 AWG, the smaller the number, the bigger the wire. Cables larger than 1 AWG are numbered 0, 00, 000, and 0000 (pronounced "one-ought," "two-ought," "three-ought," and "four-ought"). These sizes are usually written 1/0, 2/0, 3/0, and 4/0.

Cables bigger than 4/0 are referred to by their cross-sectional area, measured in circular mils (cmil), and are rarely used as portable power cable in film production. One size bigger than 4/0 is 250 cmil, for example.

Multiconductor cable is labeled with the gauge and the number of conductors, denoted (for example) as 12/3, where 12 is the gauge of the cable, and 3 is the number of conductors. Tables D.1 and D.2 list the ampacity of various sizes and temperature ratings of cable. The maximum amperage capacity for entertainment feeder cable sizes are summarized in the following table. This is the absolute maximum; under typical circumstances, the cable capacity must be derated from these figures, as we shall discuss shortly.

Maximum operating temperature

Cable manufacturers test each type of cable insulation and assign it a maximum temperature rating, which is tested and confirmed by nationally recognized testing agencies like UL. The more current runs through the cable, the warmer it becomes. The rating reflects the temperature that the wire can safely reach without damaging the insulation. When insulation becomes overheated, it may become brittle, crack apart, or melt. The temperature rating provides a margin of safety between the maximum operating temperature of the cable and its breakdown point.

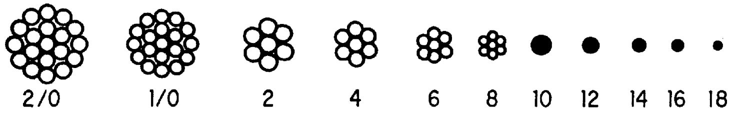

FIGURE 12.8

Diameters of common sizes of copper wires without insulation.

(From H. Richter and W. Schwan, Practical Electrical Wiring, *15th ed., New York: McGraw-Hill, 1990. Reproduced with permission of McGraw-Hill.)*

Ampacity of Feeder Cable		
	Insulation Rating of Cable	
	75 °C	**90 °C**
4/0	360 A	405 A
2/0	265 A	300 A
#2 AWG	170 A	190 A

Note: The figures given here are from the 2008 National Electrical Code table 400.5(B) for type SC, SCE, SCT and W flexible cables operated at an ambient temperature of 86 F, in free air, not placed in conduit or a raceway, where the conductors are not in contact with one another (except in sections not longer than 24-inches in order to pass through an enclosure), and where operated for less than 3 hours continuously.

Circuit breakers and fuses also have a maximum temperature rating. If a cable rated at 90 °C is connected to a fuse rated at only 75 °C, the cable must be derated to the temperature of the fuse. This is necessary because the higher rated cables transfer heat and overheat the fuse. To prevent heat transfer and work around this limitation, you can use a larger jumper cable between the fused panel and the first junction point. The jumper cable must be sized to carry the needed amperage at the lower temperature rating. The ampacity of a cable rated at 60 or 75 °C is substantially lower than that of cable rated at 90 °C. Be sure to assign the proper amperage to the cable you use.

Connectors also have a maximum amperage rating. Obviously, you must not run more power through a cable than the connector is rated for, regardless of the rating of the cable. Connectors tend to be the weakest part of the system. Bates and Edison connectors overheat and melt if they are overamped or (more commonly) if there is poor electrical contact between mated connectors, or where the wires terminate inside the connector. If a bad contact is left too long, the connector makes a noxious smell as it starts to melt and is eventually destroyed. It could also start a fire. The amperage ratings of connectors are discussed further in Chapter 13.

Other factors that affect ampacity

Ampacity is not printed on cable, because outside factors influence the operating temperature of the cable and may lower its effective maximum amperage: the ambient temperature around a cable, the number of conductors in the insulation jacket, and the spacing between single conductor cables, whether the cables are in a raceway or conduit or standing in free air. The NEC specifies how much a

cable must be derated in each of these circumstances (NEC article 400, Table 400-5B). NEC Table 310.16 provides the temperature correction factor for used when distribution cables are used at ambient temperatures above and below 86 °F. For example when the ambient temperature is between 114 and 122 °F, a cable with a temperature rating of 90 °C must be derated by a factor of 0.82. Keep this in mind when cabling. When cable runs are in well-ventilated areas, the room temperature is normal or cool, and the loads are used intermittently, no derating is necessary. Cables should never be tightly bundled or stacked one on another. If cables must be placed in narrow raceways, strung out across hot asphalt or otherwise subject to hotter than normal ambient temperatures, the cable should be derated further to protect the insulation from overheating. Keep this in mind when selecting cable gauge under such circumstances.

Continuous loads

A *continuous load* is defined by the code as a load that is expected to continue for 3 hours or more. Because electrical conductors heat up over time, when circuits are to be loaded continuously for more than 3 hours, Articles of the electrical code governing feeders (215) and branch circuits (210) both include requirements that the current carrying conductors be able to carry 100% of the non-continuous load *plus 125% of the continuous load.* This means the portion of the load that is running for greater than 3 hours must be calculated at 125%. There is an exception made if the assembly including the overcurrent protection is listed for operation at 100% of its rating, in which case the ampacity required is simply 100% of the total load. Some modern distro boxes do use 100% continuous rated breakers. If it is not 100% rated, a circuit protected by a 100 A breaker, for example, may not be loaded beyond 80 A continuously for more than 3 hours.

Types of feeder cable

Type W cable

Type W cable is a portable, extra-hard-usage power cable, manufactured to meet the requirements of NEC Article 400 (portable cords and cables) and is acceptable for temporary wiring according to Articles 520 (Theaters and Similar Locations) and 530 (Motion Picture and Television Studios and Similar Locations). It is very durable, flexible, and abrasion-resistant and usually double-insulated. It may be oil-, solvent-, and sunlight-resistant and flame-tested. Some insulation can remain flexible in very low temperatures, which is handy in cold climates.

Entertainment industry and stage-lighting cable: EISL (types SC, SCE, and SCT)

EISL cable, commonly called *entertainment cable*, is a portable, extra-hard-usage cable with the same insulation characteristics as type W cable, but is 20% smaller and lighter than type W, and also slightly less durable. You often see 105°C-rated entertainment cable used, but the 105° rating is not listed in the NEC's ampacity tables. You must use the next lower temperature rating (90 °C), and again, the temperature rating of the overcurrent protection may require the cable be derated further to the 75 °C rating.

Years ago, welding cable was commonly used for feeder, because it was more flexible and lighter than other types of cable available at the time. However, welding cable has never been approved for this purpose. The misapplication of welding cable became an issue during the 1984 Olympic Games in Los Angeles, after which there was a general conversion to type W and entertainment cable on the

West Coast. The NEC prohibits the use of welding cable in motion picture distribution systems, except as a grounding wire.

Decoding feeder cable labels

Electricians learn to identify wire gauge by appearance. Occasionally, however, you have to check the gauge by reading it off the insulation. For example, 2/0 type W cable is almost as large as type SC 4/0 cable, because the insulation is so thick.

Single-conductor feeder cables are imprinted something like this "Royal Type SCE Entertainment Industry & Stage-Lighting Cable 2/0 AWG 90°C 600 V (UL) NEC 520 & 530 Outdoor," which means:

- Royal is the manufacturer.
- Type SCE is the NEC type designation.
- Entertainment Industry & Stage-Lighting Cable is the trade name of the type of cable.
- 2/0 AWG is the size of the cable.
- 90 °C is the maximum operating temperature of the insulation.
- 600 V is the maximum voltage of the cable.
- UL indicates that the cable is listed with Underwriters Laboratories.
- NEC 520 and 530 indicate that the cable meets the requirements of NEC Articles 520 and 530, which apply to the entertainment industry.
- Outdoor indicates that the cable is approved for outdoor use.

Decoding multiconductor cable labels

Multiconductor cable, used for stingers and power cords, is marked as follows: "12/3 Type SJOW-A 90 °C P-123-MSHA—Type SJO 90 °C," which means:

- 12/3 indicates the gauge (12) and the number of conductors in the cable (3).
- Type SJOW-A is a code for the type of insulation S type cord, (J) junior service, with an (O) oil-and (W) water-resistant jacket).
- 90 °C is the maximum operating temperature of the cable.
- P-123-MSHA indicates that the cable is approved by the Mine Safety and Health Administration (MSHA).
- Type SJO 90 °C is an alternative designation given to this particular cable.

Note in Table 12.3 that junior service cable such as SJO is rated as "hard usage" cable which is permitted to be used only if it is not used in audience areas, and areas where it might be subject to physical damage. In these cases "extra hard usage" cables are required, such as SO cable.

Table 12.3 gives the meaning of some common insulation designations.

EQUIPMENT GROUNDING

To be clear, the word "ground" is used in three totally different ways in the parlance of the electrical trade:

Table 12.3 Insulation Designations (for small cables)

S	Portable cord designed to withstand wear and tear, consisting of two or more stranded conductors with a serving of cotton between the copper and the insulation to prevent the fine strands from sticking to the insulation. Fillers are twisted together with the conductors to make a round assembly held together by a fabric overbraid. The outer jacket is of rubberlike thermosetting material.
SJ	Junior service. The same as S, but with a thinner jacket. Junior service cord may not be used in areas governed by NEC Section 520-53(h), 520-62(b) (live audience situations). It may be used in other situations, as long as it is not subject to abuse (continually stepped on or rolled over).
SV	Junior service. The same as S, but with an even thinner jacket.
SO	S cord with an oil-resistant neoprene jacket. Designated for extra-hard usage.
SOW	S cord with an oil- and water-resistant jacket.
SPT	Standard two-conductor "zip cord" or household lamp card. Cord with thermoplastic insulation. Zip cord is not hard-usage or extra-hard-usage cable as required by the NEC for use by a film or TV production, except when it is part of a listed assembly.

1. *Equipment grounding*. The U-shaped prong on an Edison plug is for the equipment grounding wire. Grounding wires are not meant to carry current under normal circumstances. They carry current only when there is a fault inside a piece of equipment causing the metal housing to become electrified.
2. *Grounded neutral*. The neutral wire is sometimes called a "grounded neutral." The reason for this will become clear in a moment. Grounded neutral wires are not to be confused with *grounding* wires.
3. *System grounding*. The neutral buss of an electrical service is grounded to the earth by use of a grounding electrode sunk into the earth. The *grounding electrode conductor* is the wire that makes this connection. We'll discuss system grounding later in this chapter.

The equipment ground is a safety loop that works in conjunction with the overcurrent protection to protect people against shock from a faulty piece of equipment that has developed a short. If no grounding wire were connected (Figure 12.9A), anyone who touched the fixture would complete the circuit to ground through his or her body and would receive a shock. With a grounding wire connected to the housing (Figure 12.9B), electricity seeks the path of least resistance, and the bulk of the electricity completes the path to ground through the grounding wire instead.

The equipment grounding wire is bonded to the service panel, as is the neutral wire of the circuit. When a fault occurs, the grounding wire provides a path for the short current back to the neutral bus. Normally this will cause an overcurrent situation, which trips the breaker and removes the fault from the circuit. However, if the fault makes only loose contact (high resistance), it will create a lot of heat but may not pop the breaker. The grounding wire can be smaller than the current-carrying wires; however, it must not be so small that the resistance in the wire prevents it from tripping the breaker in case of a fault. The NEC provides a table indicating the minimum sizes for grounding wires (see Table D.3).

Another way to think of equipment grounding is the intentional connection of all exposed metal parts of the system together; this way all exposed metal ports at the same potential. A person touching any two metal surfaces will not experience a difference in potential—they won't be shocked. Proper equipment grounding is essential to safety. It is one of the things that the fire safety officer and electrical inspector look for on the set.

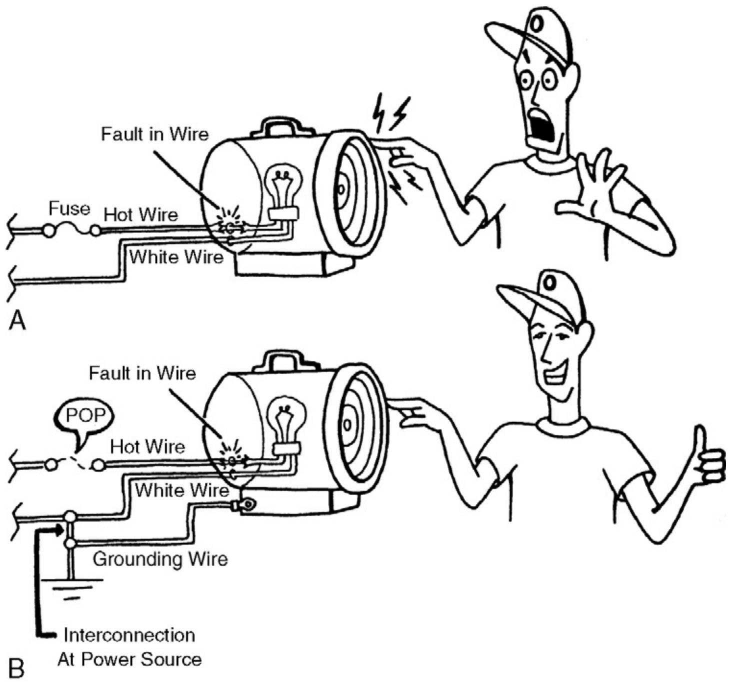

FIGURE 12.9

(A) A fault in a metal fixture energizes the entire housing. Anyone who touches the electrified fixture may complete a circuit to ground and get a shock. (B) A grounding wire carries the fault current safely to ground. Because the grounding wire and the neutral wire are bonded at the service entrance, the current carried by the grounding wire back to the service panel creates a dead short. If enough current flows through the grounding wire, the fuse or circuit breaker pops in response.

TYPES OF DISTRIBUTION CIRCUITS

There are three basic types of distribution circuits:

- Direct current
- Single-phase alternating current
- Three-phase alternating current

The power source may be the alternator windings of a generator or the secondary windings of a power transformer. In either case, there are a couple ways the distribution system may be configured. In the United States, Canada, and Mexico, the four systems we see in our line of work are:

1. Three-wire DC (240/120 V) (which is almost completely phased out)
2. Three-wire single-phase, plus ground (60 Hz AC 240/120 V)
3. Four-wire three-phase, plus ground (60 Hz AC 208Y/120 V)
4. Three wire three-phase 480 VΔ, plus ground (60 Hz AC)

In the United Kingdom, Australia, and Western Europe, higher voltage 50 Hz systems are used (415/240 V or 400/230 V AC).

Direct current

A *direct current* power source (a battery or DC generator) has a positive terminal and a negative terminal. Electrons flow from the negative terminal through the circuit to the positive terminal. The *polarity* (direction of flow) never changes, and the voltage remains at a constant value. From the beginning, motion picture studios were powered with DC, because arc lights were the only light that was bright enough to expose the slow film stocks of the time. Tungsten lights run just as brightly on DC as they do on AC, so DC was universally used. The studios built DC powerhouses and infrastructure. In the powerhouse, DC generators were driven in pairs from a large AC motor to create three-wire 240/120 V service (Figure 12.10). No ground was used. Beginning in the 1970s, things started to change. Film stocks got faster, HMIs (which are AC only) were more and more widely used and soon took over the role of arcs. Today arcs are a thing of the past, and the studios have dismantled many of the DC powerhouses. The legacy of the DC system remains here and there. Most tungsten lights still use AC/DC switches. Some old generators can provide DC concurrently with AC. Some old gaffers still prefer to use single-phase three-wire (plus ground) distribution (which works in the same way as the old three-wire DC system), rather than three-phase. Previous editions of this book discussed the DC system. If you are interested, you can find these sections archived on the *Set Lighting Technician's Handbook* Web site.

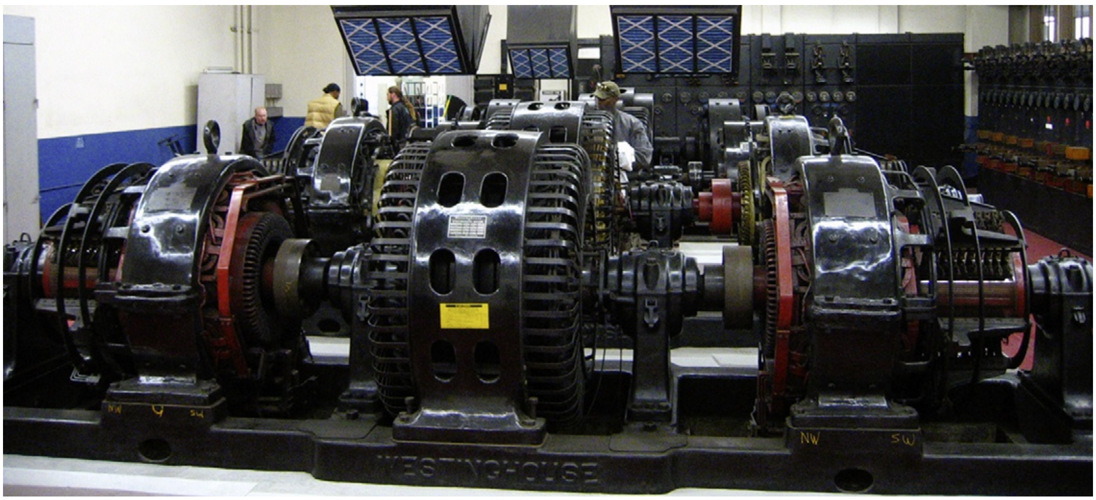

FIGURE 12.10

DC generating stations, like this one on the Paramount lot, are becoming a thing of the past. Note the huge AC motor in the center, which turns two DC generators—one on the left, one on the right. Wired in series, this creates a three-wire 240/120 V DC system. Each generator produces 120 V, with one wire being common to both generators (neutral). The voltage across the two "hot" wires is 240 V.

Alternating current

Alternating current, which is supplied by the power company through transformers or by an AC generator, has one, two, or three "hot" leads, known as the *phase leads*, and a neutral lead, sometimes called the *common*, *neutral*,[3] or *return* lead. The polarity of the circuit alternates continuously from positive to negative and back to positive again. Electrons flow first in one direction; then polarity is reversed and they flow in the other direction. The polarity changes 120 times/second in the United States, Canada and Mexico (60 cycles/second, or 60 Hz), and at 50 Hz (100 times/second) in Great Britain and Western Europe (Figure 12.11).

During each cycle, the voltage of a 60 Hz, 120 V system goes from 0 to *peak voltage*, +170 V, back to 0, reverses polarity, goes down to −170 V, and back to 0 again. It does this 60 times every second. Because the cycles occur rapidly, and because the glow of the filament of moderately large lamps decays in brightness very slowly, there is no time for the filament of a bulb to dim perceptibly during the short time when the voltage passes 0. The *effective*, or RMS (root mean square), voltage of a circuit is 120 V:

$$\frac{\sqrt{2}}{2} \times \text{peak voltage} \quad \text{or} \quad 0.707 \times 170 = 120\ \text{V}$$

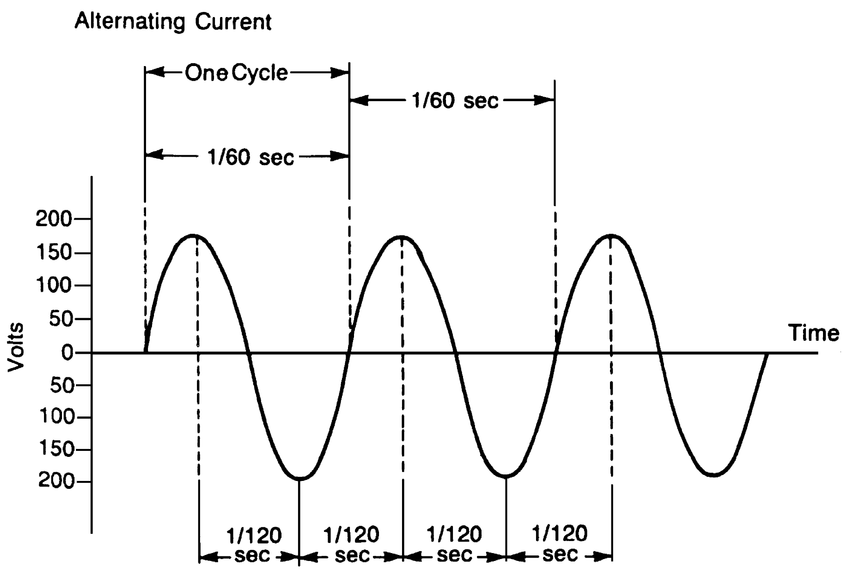

FIGURE 12.11

A 60 Hz alternating current makes one full cycle in 1/60th of a second and hits peak voltage every 1/120th of a second. Note that the effective, or RMS, voltage is 120 V.

[3] The term *grounded lead* is officially the correct term for the neutral. As *neutral* is the more familiar term to most electricians, I use it throughout this text. Officially, however, this is considered incorrect usage; the common wire is not actually "neutral" unless the phase wires are equally loaded. I do not use the term *grounded lead* because it is too easily confused with *grounding wires*.

A voltmeter reading gives you the effective voltage. A lamp connected to the circuit operates at the effective voltage of 120 V.

Alternating current: Single-phase three-wire system

Though most incandescent lights run on 120 V, larger HMIs and 20ks run on 208 V or 240 V. A single-phase three-wire AC system, which provides both 120 and 240 V power from three wires, is commonly used in film distribution systems, as well as in most homes and commercial buildings. There are a number of ways that 240/120 V single-phase power is originated; it may by created using a split coil on the secondary winding of a single-phase transformer as shown Figure 12.12. More commonly, it is derived it from a three-phase source (generator or transformer).

Regardless of how it is created, this system consists of two 120 V phase conductors and a common neutral conductor. By connecting the load between one phase and the neutral, you get 120 V. By connecting the load between the two phase conductors, you get 240 V. The neutral wire is always white. The two phase legs are usually blue and red (but may be blue, red, or black, but never white or green). A voltage reading between a phase wire and the neutral is referred to as a *phase-to-neutral* reading. A voltage reading between two phase wires is referred to as a *phase-to-phase* reading.

You might wonder whether using the neutral wire to serve two circuits doubles the load on the neutral wire. Would the neutral wire have to be twice as thick as in a single circuit to carry twice the amperage? The answer is that the load is not doubled; in fact, one phase cancels the other out. The current flowing through one phase lead always flows in the direction opposite that of the current in the other phase lead. When the loads are the same on both legs, the current in the neutral wire is

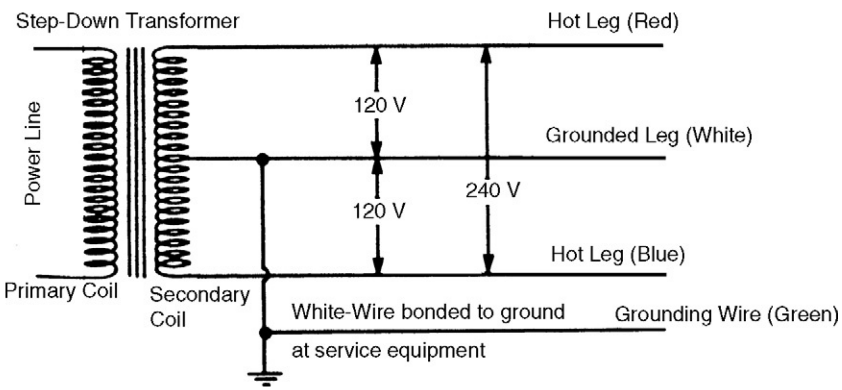

FIGURE 12.12

The three-wire 240/120 V AC configuration common in all types of buildings. The coils represent the primary and secondary coils of the transformer that steps down the voltage from the power lines. The neutral (white) wire taps into the midpoint of the secondary coil and is a grounded wire. The voltage potential is 240 V between red and blue and 120 V between white and red or between white and blue.

effectively zero. When the load on one phase is greater than that on the second, the neutral wire carries the *difference* in amperage of the two phase conductors.

For example, assume that the red leg and the blue leg are carrying 50 A each. The loads are even, so the two loads traveling through the neutral wire cancel each other out. If we remove 10 A from the red leg and put it on the blue leg, making the red leg 40 A and the blue leg 60 A, the neutral wire carries the difference of 20 A.

Note that this type of circuit actually has four wires including the ground, but it is properly referred to as a *three-wire circuit plus ground*. This gets a bit confusing, because when we order cable, we refer to our cable *as four-wire banded* (single phase) or *five-wire banded* (three phase). The phase wires and the neutral are "current-carrying wires," the fourth (or fifth) wire is a green-coded equipment grounding wire.

Note also that electrical systems are referred to as either *240/120 V* or *208/120 V three-phase*. It is not proper to refer to the US system as *220/110 V*. This is misleading and can cause confusion.

Cautions

There are a couple of disastrous mistakes to avoid when cabling. You must be careful not to connect the wires incorrectly. We use a color coded system for single-conductor distribution cable to prevent connecting the wires incorrectly. If the neutral and one phase wire were revered, the lights on one circuit receive 240 V, which blows out 120 V lamps as soon as you try to turn them on. When a plugging box is intentionally wired to serve a 240 V light, it must be clearly marked. If in any doubt, check the voltage with a voltmeter before plugging in any lights.

Second, be sure that the neutral wire is never inadvertently disconnected. This was a more common problem in the days before locking connectors were required. Although (or maybe because) this would be very unusual these days, it is important to know the symptoms of an open neutral. If the neutral wire is taken out of the circuit, the voltage applied to the circuit becomes 240 V and the two sides of the circuit become connected in series (Figure 12.13).

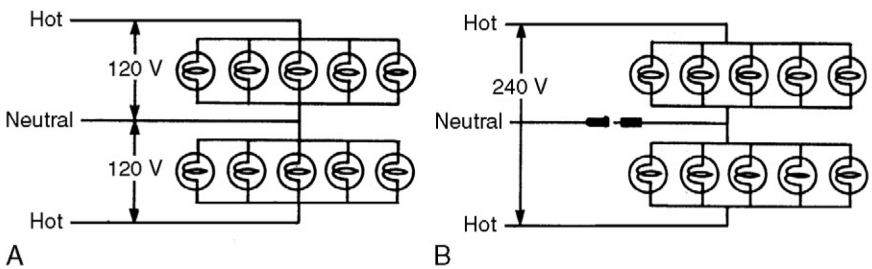

FIGURE 12.13

(A) A typical three-wire 240/120 V system with five lamps connected to each leg. The red and blue legs are separate circuits sharing the common neutral lead. (B) When the white wire is pulled, the red and blue legs become connected in series with 240 V total voltage. If both sets of lamps have exactly the same resistance, the voltage is divided evenly in two, at 120 V each. However, if one leg has more resistance, it receives more voltage and the other leg receives less. (They always add up to 240 V.)

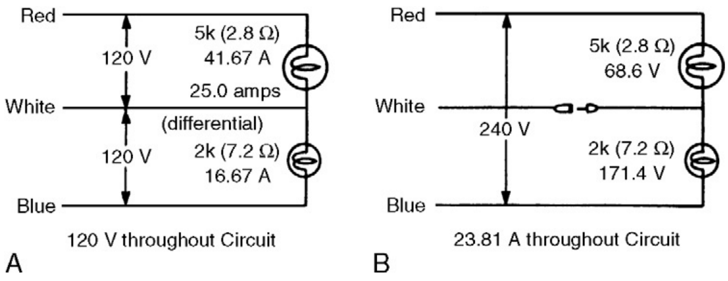

FIGURE 12.14

(A) A three-wire system with a 5k on one leg and a 2k on the other. (B) With the neutral wire disconnected, the two legs are connected in series with 240 V applied to the circuit. The 2k is blown by the 171 V overvoltage. Note that if instead of one light, each side of the circuit consists of many lights, a domino effect occurs where as each lamp blows, the imbalance in resistance increases, accelerating the rate at which all the lamps blow in quick succession.

Theoretically, if the resistance on both sides of the circuit were exactly the same, the voltage on each side would still be 120 V (240 divided by 2). However, chances are that the two phases are not evenly loaded. The difference in total resistance of one phase compared to that of the other phase creates an imbalance in the voltage. The voltage on one side of the series circuit drops, while the other side shoots up and starts to blow out bulbs on that side of the circuit in a matter of seconds.

Consider a simple example of a three-wire system with a 5k fixture on the red leg and a 2k fixture on the blue leg (Figure 12.14). With the neutral connected, each light receives 120 V. The 5k pulls 41.67 A and has a resistance of 2.88 Ω. The 2k pulls 16.67 A and has a resistance of 7.2 Ω. If the neutral wire were disconnected, the two lights would become connected in series in a 240 V circuit. Unlike a parallel circuit, the amperage in a series circuit is the same in every part of the circuit, and the total resistance of the circuit equals the sum of the resistances of all the lights.

We can calculate the amperage for the circuit as follows:

$$I(\text{total amperage}) = \frac{E(\text{total voltage of circuit})}{R(\text{sum of the resistances})}$$

$$I = \frac{240\ \text{V}}{2.88\ \Omega + 7.2\ \Omega} = 23.81\ \text{A}$$

Knowing the amperage of the whole circuit (23.81 A), we can now calculate the voltage ($E = I \times R$) being applied to each light:

$$\text{Voltage of the 5k}: 23.81\ \text{A} \times 2.88\ \Omega = 68.6\ \text{V}$$

$$\text{Voltage of the 2k}: 23.81\ \text{A} \times 7.2\ \Omega = 171.4\ \text{V}$$

From this, we can see that the fixture with the greater resistance, the 2k, receives a higher voltage, which blows the lamp. Note that the sum of the voltages of the lights is equal to the voltage of the whole circuit (68.6 V + 171.4 V = 240 V).

A little (true) story will help illustrate. A best boy had completed prerigging the cable to a set. The power was brought online, and all the power indicator lights on the distribution boxes lit up. The voltage was tested and voltage measured 120 V on each leg as normal. But when he flipped the switch on the first light, a 10k, nothing happened. He measured the voltage again, with the 10k still turned on, and lo and behold, the voltage now showed zero volts on the leg to which the 10k was connected, and 240 V on the other leg. The best boy was puzzled for a moment until he thought about the strange swing in voltage, and realized that this must be due to an open neutral connection. He immediately walked the cable line back to the generator and sure enough, found that a connector had pulled loose on the neutral conductor.

With no load on the system, the indicator lights of the distribution boxes and the voltage readings would all appear normal because the load was negligible and balanced. The resistance of the indicator lights on one leg of the circuit was so high compared to that of the 10k on the other side that virtually no voltage was applied to the 10k, while 240 V was applied to the indicator lights. Seconds after fixing the problem, the first unit crew arrived on set and started turning on all the lights. The best boy realized how lucky he was to have tried only one light. If all the lights had been energized with the neutral wire disconnected, lamps would have been blowing everywhere.

Three-phase, four-wire systems

Most commercial buildings, including soundstages, have three-phase power. Location generators also put out three-phase power. You will sometimes see the word phase abbreviated with the Greek letter phi (ϕ).

A three-phase, four-wire system consists of three 120 V phase leads (referred to as phase A, B, and C, and coded black, blue, and red) and a neutral lead (white). Each of the three phases operates at 60 cycles/s. Each phase, however, operates a third of a cycle out of phase with the next. If you think of one cycle as a 360° circle, each phase begins the cycle 120° after the last. Figure 12.15 compares the generator windings and sine wave of a single-phase generator with that of a three-phase generator.

As with the single-phase system, if all three phases are evenly loaded, the neutral wire carries no current (assuming purely resistive loads). When the phase legs are not evenly loaded, the neutral carries the difference of the phases. The difference was easy to calculate with a single-phase system, but with a three-phase system, it has to be calculated using vector geometry (because of the 120° phase difference between the legs). This leads to a rather complicated calculation. If the currents on the three phase legs are radically different from one another, you can find I_N (the current on the neutral) as follows: plug the phase currents I_A, I_B, and I_C into the following (somewhat verbose) equation:

$$I_N^2 = \left[I_A - \frac{1}{2}(I_B - I_C)\right]^2 + \frac{3}{4}(I_B - I_C)^2$$

Note that this equation calculates I *squared*, (I_N^2). You have to hit the square root key on your calculator to get I_N I *squared*.

If you are like me, you wouldn't touch this equation with a 10-foot pole, so here is a simpler rule of thumb. If two of the three phase leads are evenly loaded (say they are both right around 100 A, for example) and the third phase is loaded to, say, 60 A, the neutral carries the difference between the current on the two even phases and current of the third phase lead (100 A − 60 A = 40 A).

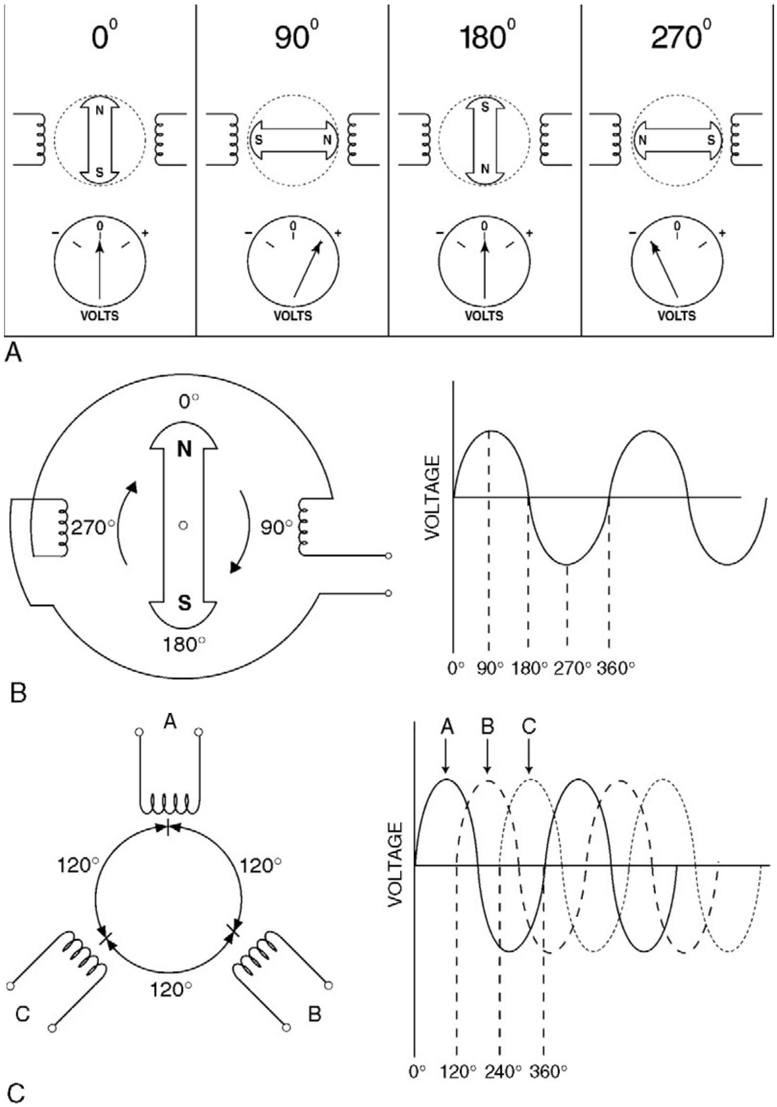

FIGURE 12.15

When a wire moves through a magnetic field, a current is induced in the wire (a voltage potential is produced that pushes the current when connected to a complete circuit). (A) A simplified diagram shows how this is used to produce electricity in an alternator (an AC generator). As the rotor (magnetic field) rotates past the armature windings, voltage increases to a maximum; current moves first in one direction (at 90°), then in the opposite direction (at 270°). As the rotor passes 0° and 180°, the voltage passes 0 and the current changes direction. (B) The result is a continuous sinusoidal waveform as the armature rotates. (C) A three-phase alternator has three sets of armature windings (A, B, and C), each spaced 120° from the last. This produces three separate sine waves, 120° out of phase, commonly referred to as the *three phases*. For simplicity and clarity, all the windings for each phase are represented here by a single winding and the rotor is not shown.

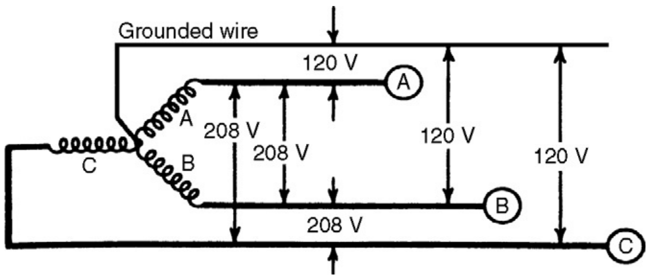

FIGURE 12.16

A 208Y/120 V three-phase system. The three coils shown represent the secondary coils of the transformers that step down the voltage from the power line. A 208/120 V system can supply 120 V single-phase loads, 208 V single-phase loads, and 208 V three-phase loads. Note: the transformer winding are not placed in this geometry (they just sit side by side), but the geometry helps illustrate the relationship of the phases and the neutral.

(From H. Richter and W. Schwan, Practical Electrical Wiring, *15th ed., New York: McGraw-Hill, 1990. Reproduced with permission of McGraw-Hill.)*

208Y/120 V system

The circuit shown in Figure 12.16 is a wye-connected three-phase system. It is called a *wye* or *star* because of its shape. When a load is connected to any one of the phase wires and the neutral wire, the voltage is 120 V. When a load is placed between any two phase wires, the voltage is 208 V because the two phases are 120° apart.

Note that a three-phase, four-wire system actually uses five wires. The fifth is a green-coded grounding wire (not shown in Figure 12.16).

There are five types of circuits that can be derived from a wye-connected, four-wire plus ground, three-phase system (Figure 12.17):

120-V, two-wire circuit plus ground, single-phase. Three separate circuits can be made by tapping any one of the phase leads and the neutral lead. When loading the three phases, it is important to keep them evenly balanced.

208-V, two-wire circuit plus ground, single-phase. This circuit is made by tapping any two of the three phase leads. The larger HMI ballasts run on 208 V. When running three-phase (208Y/120 V) power, select 208 V input power on the ballast. Again, as much as possible, keep the load evenly balanced among the phases by tapping A and B, B and C, and C and A evenly.

208/120-V, three-wire circuit plus ground, single-phase. By tapping two of the three phase leads and the neutral lead, you have the option of providing 120 or 208 V power. Doing this, you can use distribution boxes made for three-wire systems. Be sure to label each box (red/blue, blue/black, or black/red) so you remember what is plugged into what. Keep the load evenly balanced by tapping evenly: A and B, B and C, and C and A.

208-V, three-wire circuit plus ground, three-phase. This type of circuit uses all three phase leads and no neutral. Some xenon ballasts are wired this way. A service panel wired this way is usually a designated branch circuit for machinery, such as a large air-conditioning unit or three-phase motor. This circuit does not provide a neutral, and therefore cannot provide 120 V service.

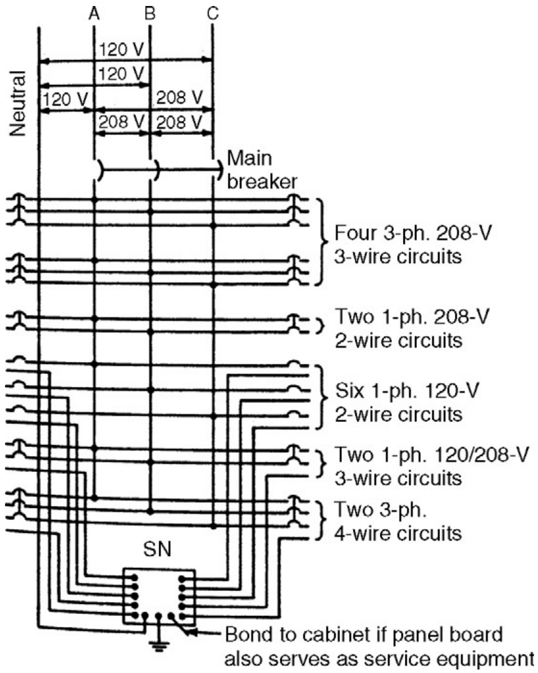

FIGURE 12.17

Five types of circuits can be derived from a 208Y/120 V (four-wire, three-phase) system.

(From H. Richter and W. Schwan, Practical Electrical Wiring, *15th ed., New York: McGraw-Hill, 1990. Reproduced with permission of McGraw-Hill.)*

(It is unsafe and forbidden by the NEC to use a ground wire tapped from another circuit to get 120 V single-phase circuits from the legs of a three-wire, three-phase system.)

208Y/120 V, four-wire circuit plus ground, three-phase. Branch circuits with this configuration provide all the possibilities described above.

Delta-connected four-wire, three-phase system

You sometimes come across a four-wire, three-phase delta-connected system. Its name comes from the circuit's resemblance to the Greek letter delta (Δ). The voltage across each of the secondary coils of the transformer is 240 V (Figure 12.18).

To supply 120/240 V service, one coil may be tapped in the center. The tap is grounded and becomes the neutral lead for a three-wire, single-phase 120/240 V circuit. Single-phase 120 V power can be gained by connecting to A and N or B and N. The tapped coil is usually larger than the other two, so it can handle the extra load.

Connecting to C and N produces 208 V, single-phase power (Figure 12.19). This is called the *high leg* or *stinger leg*, and it has caught many an electrician by surprise. If you are used to a wye configuration, you would expect any of the three phase leads to give 120 V when connected with the neutral.

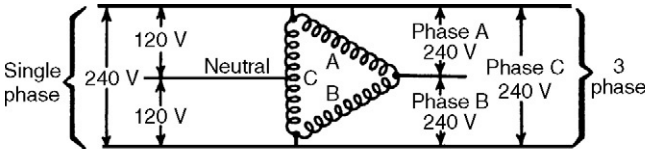

FIGURE 12.18

A 240 V, three-phase, delta-connected system delivers single-phase 240/120 V current and three-phase 240 V current.

(From H. Richter and W. Schwan, Practical Electrical Wiring, *15th ed., New York: McGraw-Hill, 1990. Reproduced with permission of McGraw-Hill.)*

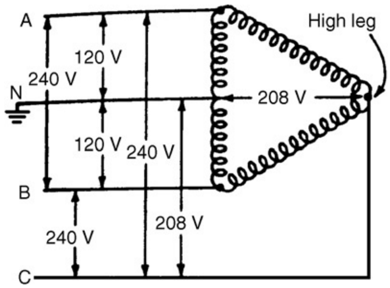

FIGURE 12.19

In a delta-connected system, the voltage from the neutral to the high leg is 208 V power, not 120 V power, as you would expect from a wye-connected system.

(From H. Richter and W. Schwan, Practical Electrical Wiring, *15th ed., New York: McGraw-Hill, 1990. Reproduced with permission of McGraw-Hill.)*

The high leg on a delta-connected system gives 208 V, because it has the added voltage of an extra half coil. Because the extra half coil is 120° out of phase, it adds 88 V to the 120 V of the full coil ($88 + 120 = 208$ V). Obviously, the high leg would burn out any 120 V light connected to it.

Other systems used in industrial applications

When shooting on location, it is sometimes convenient to tap into unused existing service. Location panel tie-ins require a permit and may be performed only by a trained and qualified person. Empty warehouses sometimes have a number of service panels and subpanels that could provide some amount of power. You may find a 208Y/120 V or 240Δ/120 V system that you can use. Other systems are also quite common in this type of environment; however, they may or may not be of any use.

Large fluorescent lighting installations operate more efficiently on 277 V power, so most industrial buildings and high-rises use a 480Y/277 V system. The system is on a separate transformer from the 120 V service. This system requires a 480 V delta to 208/120 V wye step-down transformer to be a usable power source.

Buildings may be supplied with a variety of different configurations beyond what I have mentioned here. A qualified electrician is needed to determine what circuits might be appropriate for our equipment.

SYSTEM GROUNDING

The neutral bus bar at the service entrance (the main panel where power enters the building) is bonded to the grounding bus, and it in turn is grounded to earth by means of a *grounding electrode conductor* connected to a grounding electrode sunk in earth (e.g., a ground rod, sunken building steel, or a made electrode, which is a large electrode placed in the ground during construction). This is the *system ground*. The system ground establishes ground potential for the neutral bus. Because the neutral bus is grounded the white wire (neutral) of a distribution system is sometimes called a *grounded* lead. For utility power, the leads coming from the transformers on the power line provide phase only. The ground and neutral are created at the service equipment where the wires enter the building.

In the case of portable generators, the frame of the generator is also bonded to the neutral buss. Depending on the AHJ,[4] a generator may be run as an isolated system without a grounding electrode, or may be required to be grounded via a grounding electrode. The grounding of generators is discussed in more detail in Chapter 16. It might seem odd to bond the equipment grounding wires to the neutral, because the neutral carries current. It might seem like this would make the entire equipment grounding system live. It does quite the opposite. Let's look at why this is.

When a source of electrical power is isolated from ground, the only fixed quantity is the voltage potential created between the wires coming out of the alternator. The voltage potential from any part of the circuit to ground is not defined. With no reference to ground, it is as if the phases are floating. It is like an airplane flying very low in fog, where the pilot can't see the hills below him. We know the phase potential is 120 V higher, but we don't really know higher than what? Like the airplane, the relation to the ground is floating, changing with the unseen updrafts and downdrafts (this plane does not have any fancy instruments). As long as nothing comes along to make a connection to ground this situation, an isolated power source, can function just fine. However if someone were to touch a grounded part of the equipment while making good contact to ground (a metal railing), then they would receive a shock equal to the difference in potential between the arbitrary floating power source and ground.

Connecting a grounding electrode to the neutral bus of a power source gives the source its relation to ground—it establishes zero-potential between neutral and ground. The phase and neutral wires are not just 120 V volts from one another, the phase is now 120 V above ground. It is like clearing the fog for the pilot. He can now clearly see the distance from the earth. No appreciable current needs to flow through the grounding electrode conductor to establish this relationship, but once it is established, *all equipment* connected to the power source has the same zero-potential relation to ground. All equipment is connected to ground by virtue of their equipment grounding

[4]Authority Having Jurisdiction. Depending on where the work is taking place the Authority Having Jurisdiction (AHJ) may be the local city electrical inspector, the fire marshal (also known as a Film Safety Officer), or the studio's safety officer. The AHJ is the ultimate authority for what practices will be allowed on set.

conductors that connects them to the neutral bus, and then the neutral bus connects to ground by virtue of the system grounding electrode.

When two or more independent power sources are used in proximity to one another, it is likely that some potential exists between them. To use the (somewhat dubious) pilot analogy again, it is as if we now have a pair of pilots flying low in fog, with no visual reference to each other or the ground. Without something to establish a relationship between the power sources, we do not know what potential may exist between them. Sounds like trouble, right? If a person were to touch the casing of a piece of equipment grounded to one power source and at the same time touch the casing of another piece of equipment grounded to the other source, they might find a dangerous potential existing between them. This is why a bonding conductor is used to create a zero-potential relationship between power sources. Here again the bonding conductor does not carry any appreciable current, but once it is established, all the equipment used on both power sources will have the same zero-potential to ground and to each other. When two power sources are bonded, they must both be connected to a single grounding electrode. There can be only one system ground.

When power is supplied to the set by two or more separately derived systems (two generators, or a generator and house power), the systems must be bonded. In the case of bonding a generator to a building's service, the bond must be made to the building's grounding electrode conductor. In the case of two generators, the bonding wire connects from one generator's ground buss to the other's. Bonding is not necessary if the two systems do not operate in close proximity to one another. For practical purposes "close proximity" is interpreted to mean that no piece of equipment connected to one power source is within 20 ft. of any piece of equipment connected to the second power source. Twenty feet is the length of the largest piece of metal generally carried by a film crew (20 × 20 aluminum frame). It is essential that the two systems have the same ground potential; otherwise, the two proximate systems present a serious shock hazard.

CHAPTER

13 Distribution and dimming equipment

In this chapter, we discuss portable electrical distribution equipment and dimming systems—that is, all the cable and electrical equipment that is needed between the power source and the lights. It is helpful to know a bit about the design and operation of this equipment, and applicable rules of the electrical code. Before we launch into the nitty gritty, let's just take a moment to distinguish what this chapter is *not* about. The discussion in this chapter concerns *portable* electrical distribution equipment, rather than permanently installed distribution. The portable system gives us great flexibility in the design of our electrical distribution. NEC regulations authorize portable systems for *indoor and outdoor* use as long as the portable distribution system is supervised by a qualified person (a lighting technician) whenever it is energized. In this chapter, we concern ourselves only with *dry* locations. See Chapter 17 for safety practices in wet locations. The distribution system described here is used throughout the United States. In Canada, Europe and elsewhere in the world the applicable electrical codes will vary. The connector types and other details are also different. In Chapters 14 and 15, we will discuss more about the planning and practices necessary for the physical installation of the distribution system. This chapter concerns itself with the gear that joins one piece of copper to another so that electrons can find their way to the lights.

COMPONENTS OF A DISTRIBUTION SYSTEM

As discussed in Chapter 12, AC distribution systems in North America are as follows:[1]

- Three-phase AC system (208Y/120 V) comprising *five wires*:
  - Three-phase wires (color-coded blue, black, and red)
  - Neutral (white)
  - Equipment ground (green)
- Single-phase AC system (240/120 V) comprising *four wires*:
  - Two-phase wires (red and blue)
  - Neutral (white)
  - Equipment ground (green)

[1]DC power and distribution was covered in detail in previous editions of this book. In this edition it has been removed to make room for new material. The vintage material will be archived on this book's Web site.

Set Lighting Technician's Handbook, 4e. DOI: 10.1016/B978-0-240-81075-1.00013-1

Distribution equipment is available in both five-wire and four-wire configurations. The components of a distribution system provide a structure of overcurrent protection whereby every smaller branch circuit is protected by progressively smaller overcurrent protection. System components between the power source and the load may include the following:

Main disconnect: The main disconnect, a bull switch that provides a main switch to shut down power to all circuits connected to it (at the end of the day or in an emergency). The disconnect may also provide overcurrent protection for the main feeders, as is sometimes required by the NEC. The power source (generator or utility) often provides a means of de-energizing the circuit, so a portable main disconnect is sometimes not necessary.

Main feeder cable: This cable, usually 4/0 or 2/0 copper cable, carries power from the power source to the set. The most common connectors for feeder cable are Cam-Lok and lugs. A number of other connector types that have been put into service at various times that are still in use. In our business, we generally do not use any cable bigger than 4/0. In order to handle larger loads, we simply increase the number of 4/0 conductors used for each phase and neutral wire. This is called *paralleling* the cable.

Splicing boxes: A splicing box divides the main feeder line into trunk lines or subfeeders. Splicing boxes are commonly referred to as *spider boxes* or *junction boxes*. Most spider boxes do not provide overcurrent protection.

Subfeeders: Smaller-gauge feeder cable delivers power from the spider box to subsequent distribution boxes. 2/0 or Banded #2 AWG cable is typical. (Banded cable is simply four or five single conductors held together in a bundle by bands of tape at regular intervals.) Cam-Lok or Mole-pin common connectors used on subfeeders.

Distribution boxes: Feeder cables terminate into distribution boxes, which provide a point to subdivide into power outlets with individual overcurrent protection (as required by NEC Article 240-21). A variety of distribution boxes are available configured with different combinations of output connectors depending on the intended use—100 A Bates, 60 A Bates, 100 A/240 V Bates, Edison duplex, Socapex, or what have you.

Dimmers: A dimmer pack or dimmer rack is a unit that contains multiple dimmers. The pack is typically powered from the main feeder and used to control some or all of the incandescent lights. Dimmers are available with standard capacities of 24, 12, 6, 2.4, 1.8, and 1.2 kW. The dimmer system typically provides fully rated magnetic circuit breaker (100% continuous loading) for each output circuit.

Extension cables and fixture cables: Extension cables, typically 25, 50, or 100 ft. in length, run from the distribution boxes to lights and smaller outlet boxes. 100 or 60 A Bates are the most common, but extensions come in all types. A *stinger* is an Edison extension cable (16 A).

Edison outlet boxes: Gang boxes, quad boxes, or lunch boxes connect to 100 or 60 A extensions to provide 20 A circuits for plugging in the smaller lights.

Main disconnect and overcurrent protection for feeders

A disconnect has two possible purposes: (1) to provide a switch to de-energize the system (this is in addition to the means provided on the generator or utility power source and would be employed for convenience), and (2) to provide overcurrent protection for the feeder cables (Figure 13.1). Not all

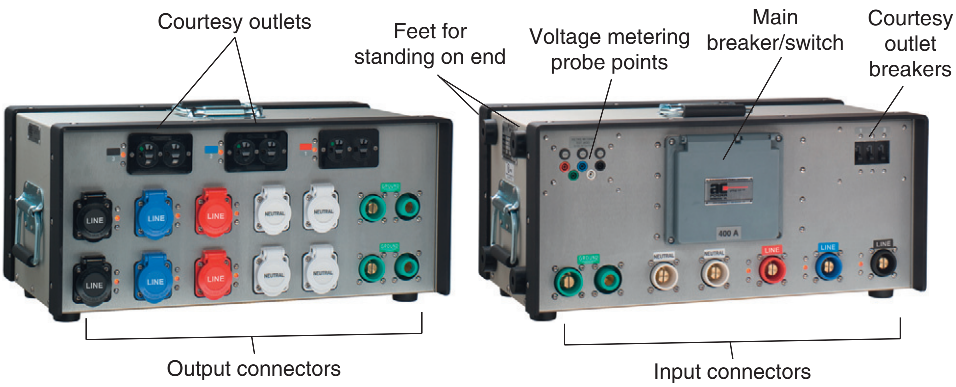

FIGURE 13.1

Disconnect Portable Company Switch. This particular model is rated for outdoor applications (NEMA 3R) and has an adjustable overcurrent device that can be set for amperages of 160 and 400 A, depending on the size cable being protected. The breaker is rated for 100% continuous duty. The outputs provide for paralleled cables and double neutral (required for between nonlinear loads such as dimmers).

(Courtesy AC Power Distribution, Inc.)

disconnects have overcurrent protection, so when you need it for this purpose, the overcurrent protection has to be specified when ordered. Overcurrent protection (circuit breaker or a set of fuses) may be required any time there is a step down in conductor size, such as when the overcurrent protection of the power source is higher than the ampacity of the feeder cables, or when a smaller feeder cable is branched off from the main feeder at a spider box.

For example, if the generator can provide 800 A per phase, and you are connecting banded cable (rated at 170 A), you need to provide overcurrent protection for the smaller cable. To do this, you would run short jumper cables to a required overcurrent protection device (such as an appropriately sized disconnect), then connect the feeder cable run to the disconnect.

There are three different code requirements that come into play here with regard to (1) when overcurrent protection is required, (2) the allowable length of the jumper cables, and (3) the required rating of the overcurrent protection provided by the disconnect. This gets a little convoluted, so bear with me.

400% rule

The national electrical code normally requires that the overcurrent protection not be larger than the ampacity of the cables being protected. However, section 530.18 A allows a special exception for motion picture work, known as the 400% rule. According to this rule, the overcurrent protection may be up to 400% of the capacity of the cables. (Just to be clear: this allows you to oversize the circuit protection, but does *not* allow you to overload the cable!) This rule was originally written when DC was in common use, although DC or AC is not specified by the rule. The rule enabled electricians to connect cables to the studio's very high capacity DC panels using cable rated at one-quarter the capacity of the overcurrent protection of the panel. For example, if you have a 1600A service and you need less than 400 A, you could connect a piece of 4/0 cable (rated at 400 A)

to the service panel, without having to add any additional circuit protection. Depending on the jurisdiction in which you are working, the 400% exemption may not be allowed. If allowed, you may take advantage of this rule if you need to, but if you are attaching a cable run that is more than 25 ft. safety dictates that you provide overcurrent protection that is rated for the cables you are using. The AHJ can require this, despite the 400% rule.

Length and size of tap conductors

When you insert an overcurrent device (such as a fused disconnect), the length of the jumper cable (NEC 240.21(B) calls them *tap conductors*) from the power source to the disconnect may not be more than:

- 10 ft. if ampacity of the tap conductors is sufficient to power the combined calculated load on the circuits supplied, and the ampacity of the tap conductors is not less than the overcurrent protection provided by the disconnect.
- 25 ft. if the rating of the overcurrent protection of the feeder is not more than *three* times the ampacity of the tap conductors, and the tap conductors terminate into a *single* circuit breaker or set of fuses that limit the load to the ampacity of the tap conductors.

So, using the earlier example, if banded cable were connected to a power source that provides overcurrent protection at 800 A per leg, the jumper cables could not be more than 10 ft. in length because the power source (800 A) is more than three times the ampacity of the jumper (170 A). Additionally the rating of the overcurrent protection of the disconnect could not be more than 170 A. You could use 4/0 jumper cables up to 25 ft. in length, from the power source to the disconnect. In this case, the overcurrent protection of the disconnect would need to match the ampacity of the 4/0 tap conductors.[2]

Similarly, when you step down the cable size at a spider box, overcurrent protection must be provided within 10 or 25 ft. in accordance with NEC 250.21(B).

Size of circuit protection

On feeder runs, it is permissible to use the next larger standard size circuit breaker if the cable ampactiy falls between standard circuit breaker sizes (NEC 240.4(B)). Remember also that you are allowed to load the overcurrent device continuously only up to 80% of the rating of the overcurrent device, unless the breaker is rated for 100% continuous use. Continuous-use breakers are much more expensive, so most distribution equipment is not so equipped; however, some are, like the one shown in Figure 13.1 and if so, they will be labeled as such.

Cam-Lok connectors

The code requires that single-conductor cable use locking connectors such as lugs, Cam-Lok, or MoleLock. Table 13.1 shows how each connector is rated.

Cam-Lok is widely used for main feeder (4/0 and 2/0 cable) as well as subfeeder (banded cable #2 AWG (Figure 14.2A)) and for large lights. Cam-Lok is also the most common input connector for dimmer racks and packs. Male and female Cam-Lok connectors are mated by lining up the arrows,

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[2]Table 400-5(8) of the NEC lists Type W and Entertainment Cable, with a temperature rating of 90° or higher, as having an ampacity of 405 A.

Table 13.1 Ampacity of feeder cable connectors			
	4/0 Cable (A)	**2/0 Cable (A)**	**#2 Cable (Banded) (A)**
Cam-Lok (1016 series connectors)	400	300	190
Lugs	400	300	200
MoleLock	NA	200	150

inserting the male connector, and then twisting the male 180°, which engages a locking pin into a cam mechanism that pulls the connectors tightly together. No tools are necessary. The cam ensures full contact, yet is relatively easy to connect and disconnect. To ensure a good connection, the connectors must be twisted until tight, not simply inserted.

Cam-Lok connectors are insulated so that no bare metal is exposed, and the connection is protected from water (the rubber shell type are typically rated NEMA 3R or 3R and 4; see Appendix E). The sleeves are color-coded red, blue, black, white, or green, appropriately. Cam-Lok connectors should not be connected or disconnected "hot" (when powering a load). This is true for all connectors but especially with Cam-Loks, because if the pin within the Cam-Lok connector gets pitted and warped from arcing, it can eventually seize up and the connectors become permanently stuck together.

There are various kinds of Cam-Lok adapters (lug to cam, cam to Bates), three-fers, and suicide pins (some of which are shown in Figure 13.2). A Cam-Lok T allows two Cam-Lok connectors to be plugged into one. A "soft two-fer" or "soft three-fer" is simply two or three female connectors wired to one male connector with a short piece of wire. A suicide pin is a male-to-male adapter typically used to reverse the direction of the connectors on the grounding wire (some companies run their ground in reverse; others don't). It gets its name from the fact that when the adapter is plugged into an energized phase, it exposes a hot pin. Obviously, you should never leave a bare suicide pin plugged into a live wire.

FIGURE 13.2

(A) Cam-Lok banded #2 cable (B) Cam-Lok three-fer; (C) Cam-Lok to 100 A, 240 V Stage Pin adapter; (D) Cam-Lok to two 100 A, 120 V Stage Pin adapter.

(Courtesy Mole-Richardson Co., Los Angeles, CA.)

Within the US film industry, when we refer to a Cam-Lok connector, we are talking about the 400 A, 600 V Cam-Lok connector, which is referred to by different manufacturers as CLS or 1016. Not all 1016 connectors are rated for 400 A; the rating depends on the size of the conductor it is designed for as indicated in Table 13.1. There are other sizes and types of cam connectors. Minicams (CLM or 1015 series connectors) are smaller 150 A, 600 V connectors commonly used in touring and similar live events and in the film industry in Canada.

Reversed ground system

With pin and Cam-Lok connectors, the male and female are oriented with "pins to power," meaning that the male pins point toward the power plant and the female end goes toward the lights. This is true of all cable, except the ground. In our industry, a reverse ground system has been widely adopted. Most equipment (banded cable and distro boxes with panel-mounted connectors) is set up with the ground reversed. The male connector on the grounding wire points downstream, toward the load. The idea is to make it impossible to plug a hot wire into the grounding wire by mistake. Because this system is not universally used, you will find distribution boxes that provide both male and female connectors for the ground (as shown in Figure 13.1).

Cam-Lok spiders

A spider box is necessary when you want to break off runs in different directions—for example, when several dimmer packs or distro boxes need to be plugged into the main run. The Cam-Lok spider shown in Figure 13.3 provides two rows of parallel inputs and six rows of outputs. This box accommodates a double 4/0 run input (2400 A max). It has double neutral connectors for handling

FIGURE 13.3

This 2400 A Cam-Lok spider has two rows of parallel 4/0 inputs (note that the second set of male connectors are capped when not in use). The spider can branch to as many as six rows of outputs. The neutral is doubled in accordance with 130% requirements for electronic ballasts and dimmers. It also features test jacks, indicator lights, and a courtesy outlet (handy for a work light).

(Courtesy Mole-Richardson Co., Los Angeles, CA.)

nonlinear loads (more about this in the next chapter). It also features indicator lights on each phase and test jacks that are protected by small circuit breakers. These test jacks are actually an important feature, because there is a lot of energy traveling through the spider. Protected test jacks allow voltage and frequency to be metered and monitored safely.

Note that regardless of how many connectors are available on a spider, the total amperage is rated based on the size and spacing of the buss bars inside. Check the manufacturer's rating of the buss bars. Some manufacturers make 1200 A spiders with four parallel input connectors, for example. This does not allow you to put 4800 A through the spider; it simply allows the use of parallel cables for voltage drop mitigation, but the current is still limited to 1200 A by the size and spacing of the buss bars. (We'll talk more about voltage drop in Chapter 14.)

Table 13.2 gives a few common configurations for Cam-Lok spider boxes.

When a spider box is used to splice smaller subfeeders to the main run, overcurrent protection is required within 10 or 25 ft. of the reduction of cable size as per NEC Article 240.21(B). A disconnect or other distribution box that provides overcurrent protection rated for the new cable size must be provided. If the 10 ft. rule is adhered to, this may be a distribution box that breaks out to multiple 100 A outlets with individual 100 A circuit breakers, but it may not provide feed-through that does not have overcurrent protection. (If a feed through distro box is all that is available, you can simply tape over the feed-through and attach a note that reads "DO NOT USE.") The 25 ft. rule requires that the jumper terminates into a *single* overcurrent device, like a disconnect, so it does not allow termination into a distribution box that breaks out into multiple 100 A circuits.

It is perfectly fine to connect loads that provide their own circuit breaker (e.g., an HMI ballast) directly into a spider box, as long as the power cord is not more than 25 ft. long. Dimmer racks can also be connected directly to the main run; however (unless the rack provides a *single* main circuit breaker on the input side), the tap conductors must follow the 10 ft. rule.

Here again, if the jurisdiction allows it, the 400% rule can be applied if necessary. For example, if the main feeder is protected by a 400 A overcurrent protection, then you may attach wire as small as 100 A extensions (using a snake-bite Cam-Lok to 100 A Bates adaptor) without having to provide

Table 13.2 Three-phase Cam-Lok spider boxes

Cam-Lok spider box (three-phase)	Number of parallel cables INPUT	Number of parallel outputs
1200 A Spider	1	3
1200 A Spider	1	7
1200 A Spider	2[a]	6
1200 A Spider	4[a]	4
2400 A Spider	2	6
4800 A Spider	4	4

[a] *Note that the number of parallel inputs is* not *necessarily an indication the maximum capacity of the spider. Even though the spider may have two or four parallel inputs, the amperage capacity is limited by the size and spacing of the internal buss bars; in this case, the capacity is 400 A per phase.*

additional circuit protection. However, if the main feeder is protected by an 800 A overcurrent device, then banded cable (#2 AWG) or anything smaller would have to be furnished with overcurrent protection in accordance with the 10 or 25 ft. rules.

Lugs and buss bars

Lug connectors are one of the few remaining components still in commission from the original DC system that was once employed in Hollywood. Lugs are heavy-duty bronze-cast clamps used on 4/0 and 2/0 feeder cable that bolt onto the copper buss bars of the service, generator or spider boxes (Figure 13.4). Spiders are necessary to join lengths of lug-cable or divide power in several directions.

Buss bars have a maximum ampacity of 1000 A per square inch of cross-sectional area. In other words, a 1/4-in. bar, 4 in. wide can carry 1000 A ($1/4 \times 4 = 1$). When connecting lugs to the power supply busses, use a crescent wrench or speed wrench (ratcheted makes the work faster) to ensure a tight connection. Always place the lug nuts on the right side of the buss bar. We do this because the nuts chew up the bars. If you chew up both sides of the buss bar, the flat part of the lug no longer makes good contact with the buss bar.

Buss bar spider boxes

On Mole-Richardson's design, each bar can accommodate between four and eight lugs. Holes in the Plexiglas frame provide access to the lug bolts, which are tightened to the bars using a T-handle 3/16-in. Allen wrench.

Westinghouse spiders are made of opaque gray nonconductive materials. The ampacity per cable and per bar of a spider box is determined by the number of lugs per bar. See the amperage data in Table 13.3.

Spider boxes can be ordered for either four-wire or five-wire power systems (Figure 13.5). Five-bar spiders provide four bars (blue, black, red, and white) plus a green grounding bar for three-phase systems. *Warning: Never use a green buss bar as a current-carrying buss; it is a grounding bar only.* The green buss bar is connected directly to the external metal straps and handles, which create a serious short and shock hazard if the buss bar is connected to a hot lead.

Spiders come in different configurations. Small (two holes per bar), larger (four holes per bar), and the super spider (four holes per bar plus two neutral busses for double neutral applications). The maximum amperage rating of the buss bars is specific to the particular model of spider box. Check the manufacturer's label for (1) the total current-carrying capacity of the spider and (2) the rating per cable.

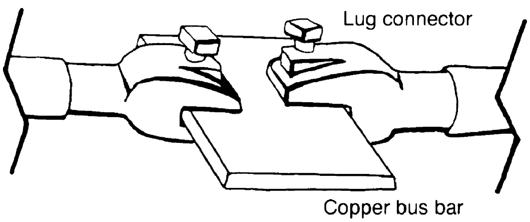


FIGURE 13.4

Lugs attach to a buss bar or spider box.

Table 13.3 Ampacity of spider boxes

	Continuous		Intermittent			
Cable Slots per Bar	**Amps per Cable**	**Amps per Bar**	**Amps per Cable**	**Amps per Bar**	**Minutes On**	**Minutes Off**
4	300	600	325	650	20	6
6	280	840	325	975	20	10
8	270	1080	325	1300	20	14

Note: The amperage data in Table 13.3 apply to spider boxes that are not listed if they have the same number of lugs per bar. This table gives Mole-Richardson's recommended maximum loading.

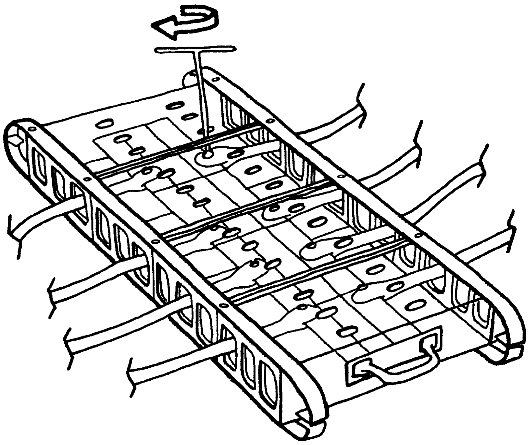


FIGURE 13.5

A four-bar spider box allows up to six lugs per bar. Lug nuts are tightened with a T-handle Allen wrench through the holes in the Plexiglas frame.

Mole pin connectors

MoleLocks are locking connectors that evolved from the old Mole pin system. The slip pins are basically unchanged, 0.515-in. diameter slip-pin connectors, but they are housed in a hard plastic color-coded sleeve that twist-locks to the mating sleeve once the pin is fully inserted. Mole pins are used on subfeeder cables and on the head cables of some larger lights. A lug-to-Mole pin adapter or jumper connects Mole pin feeders to the spider box. Mole pin connectors are used for 2/0 cable (and rated at 200 A) and on banded #2 AWG cable (and rated at 150 A). Mole pins can fit cable sizes from 2/0 to as small as 10 AWG. A full complement of adaptors and three-fers are available for Mole pin connectors, just as they are for Cam-Lok.

DISTRIBUTION BOXES

You will sometimes come across the terms *feeder circuit* and *branch circuit*. The NEC defines a feeder circuit as the wiring up to and including the final overcurrent protection device. A branch circuit is any wiring downstream from the final overcurrent protection. In accordance with the type of connectors used, the main feeder-run terminates into some sort of distribution box. The distro box provides overcurrent protection for subsequent smaller circuits, which power the lights. If there is no further overcurrent protection downstream, this would represent the end of the feeder circuit, and any connector plugged into the distro box would represent the beginning of the branch circuit. A wide variety of AC distribution boxes are manufactured to make any transition you might need. Configurations typically include a combination of output connectors and usually also include a courtesy 20 A duplex outlet. In the United States, Bates (Stage Pin) connectors are typical for 100 and 60 A branch circuits.

Some common configurations are described in Table 13.4. Almost all boxes are available in either single-phase (four-wire) or three-phase (five-wire) versions. Figure 13.6 shows some typical distribution boxes.

Table 13.4 Common configurations of distribution boxes

Distribution box	Input	Output connectors	
400 A Single-phase Box	Single-phase, Cam-Lok	4	100 A Stage Pin (120 V)
			Cam-Lok Pass-through
			Duplex Edison courtesy outlet (120 V)
600 A Single-phase Box	Single-phase Cam-Lok	2	100 A Stage Pin (120 V)
		2	240 V, 100 A Stage Pin
			Cam-Lok Pass-through
			Duplex Edison courtesy outlet (120 V)
600 A Three-phase Box	Three-phase Cam-Lok	6	100 A Stage Pin (120 V)
			Cam-Lok Pass-through
			Duplex Edison courtesy outlet (120 V)
900 A Three-phase Box	Three-phase Cam-Lok	3	100 A Stage Pin (120 V)
		3	208 V, 100 A Stage Pin
			Cam-Lok Pass-through
			Duplex Edison courtesy outlet (120 V)
1200 A Three-phase Box	Three-phase Cam-Lok	6	100 A Stage Pin (120 V)
		3	208 V, 100 A Stage Pin
			Cam-Lok Pass-through
			Duplex Edison courtesy outlet (120 V)
1200 A Three-phase Box	Three-phase Cam-Lok	12	100 A Stage Pin (120 V)
			Cam-Lok Pass-through
			Duplex Edison courtesy outlet (120 V)
1200 A Three-phase Box	Three-phase Cam-Lok	6	208 V 100 A Stage Pin
			Cam-Lok Pass-through
			Duplex Edison courtesy outlet (120 V)

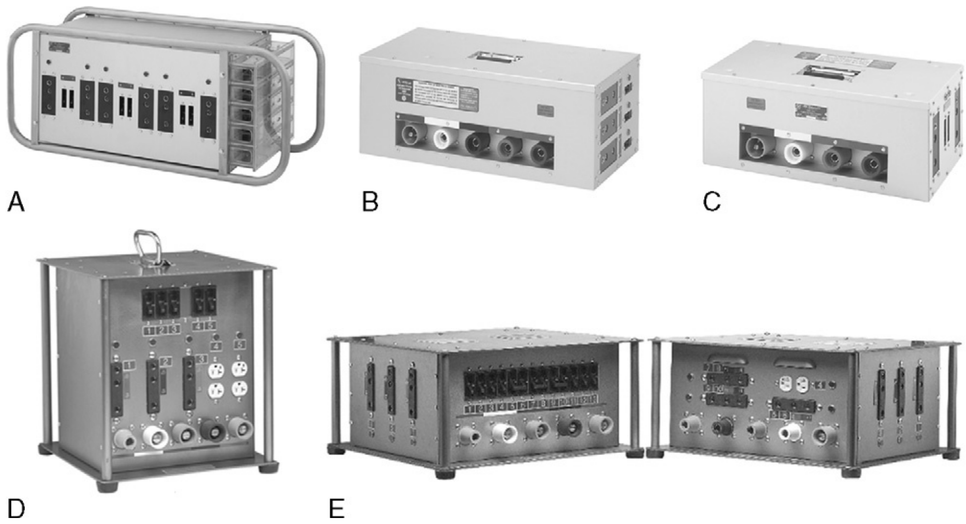


FIGURE 13.6

(A) 1200 A, three-phase lug box, lug inputs, twelve 100 A outputs; (B) 600 A, three-phase box: six 100 A outputs and 20 A duplex courtesy outlet; (C) 400 A single-phase version of the MoleLock box; (D) Dadco cat box, reduces cable spaghetti in catwalks by having all cable flow in one direction; (E) 1200 A Duzz-all Distro, outputs are six 100 A, three 100 A 240 V, and one 20 A duplex courtesy outlet.

(A, B, and C: courtesy Mole-Richardson Co.; D, and E: courtesy Dadco.)

A three-phase 208/120 V system has the advantage that it allows the maximum capacity from a generator. A 240/120 V system reduces the amount of amperage one can draw from the same generator; however, it does have other advantages. Some gaffers love the three-wire (plus ground) single-phase 240/120 V system, because at 240 V HMIs are more stable and require less current than when run at 208 V. It is easier to balance loads (240 loads are automatically balanced), the distro boxes are smaller, and a single-phase cable run because it uses less feeder cable, thus requires less work—you can make a seven-piece run instead of a nine-piece run, or a four-piece run instead of a five-piece run.

Some questions to consider when ordering boxes:

Single-phase or three-phase?
Input connector type?
AC/DC or AC only?
Do you need 240 V, 100 A outlets for 12ks, 18ks, and 20ks?
Do you want some boxes that feed through?

Distribution boxes are designed in different ways with various useful features that you might like to have. Indicator lights help with troubleshooting. Courtesy outlets allow you to attach a small work light at each box in a dark stage. On catwalks, it is often preferable to use boxes that feed in and out along only one axis (Figure 13.6D). This keeps the cable runs a lot neater than boxes that feed out in four directions. Some boxes can be stood on end, taking up less horizontal space. Some boxes are

arranged in such a way that you cannot connect hard three-fers directly to the box because they run into each other or the ground. Use three-fers with tails to connect to these boxes.

Some manufacturers incorporate a set of banana plug outlets for testing the circuits with a multimeter as was shown in Figure 13.3. This brilliantly simple idea allows you to set your meter on top of the distribution box, and leave it there to monitor the power. It eliminates the need to insert meter probes into connectors to find bare copper. As voltage-checking is something we do routinely, it makes the job easier if all distro boxes are supplied with a way to safely connect a test meter. A small fuse protects the banana plugs.

Big lights

24k lights (PAR arrays, Fresnels, and HMIs), cannot be powered continuously from a 240 V, 100 A Bates outlet: it would be running constantly at the maximum rating of the connector and the circuit breaker, and breaker trips and meltdowns would be inevitable. These lights typically have Cam-Lok connectors and can be powered from a special distribution box with female Cam-Lok outputs protected by 125 A circuit breakers.

A similar problem exists with connectors used with 12k tungsten lamps such as the ARRI T-12. When fitted with a 100 A connector and run for hours at a time, the connector is being seriously overstressed. A solution some gaffers and best boys employ is to fit the light with a 240 V, 100 A Stage Pin connector and use a 240 V lamp in the light. This eliminates problems with overheating the connectors, because current is sliced in half. This also helps balance the large load between separate phases of the distribution system. On a single-phase power system, when 12ks can balance themselves between two phases, the system will always remain perfectly balanced. Even on a three-phase system, the load creates a smaller disparity when split between two of the three phases as it would on a single 120 V circuit. GE does not make a 208 V version of the 12 kW tungsten lamp, but they do make a 230 V version, which has a color temperature of 3400 K. If you are using 208 V power, you can use 230 V lamp with only a slight sacrifice in output, and the color temperature will wind up close to 3200 K.

Remote controlled distribution boxes

A few different methods have been devised to provide remote on/off control of individual circuits from specially equipped distribution boxes. A variety of them are shown in Figure 13.7. Mole makes three-phase DMX512-controlled remote boxes with six 100 A Bates outputs (Figure 13.7B). Each 100 A circuit can be switched via a DMX512 signal. In the days of DC distribution, this type of control was provided by remote switches connected to "deuce boards" or DC cans with remote-controlled contactors. Mole's modern AC/DC deuce board (Figure 13.7D) evolved for use with three-wire AC or DC using Cam-Lok inputs and providing eight 100 A Bates outlets, each with 100 A breaker protection. The modern deuce boards still have two contactors (switches) per box, controlling four outlets per switch. Control is via a DMX512 control signal run to a dimmer board or DMX512 switch box. A DMX512 switch box (Figure 13.7 A) generates a DMX512 signal to provide on/off control of distro boxes, or relay boxes, an alternative to using a control console.

You can control old-style deuce boards with DMX512 by employing a DMX relay box (Figure 13.7D). The 24-channel relay box can control up to eight old-style two-unit type 3801 deuce boards.

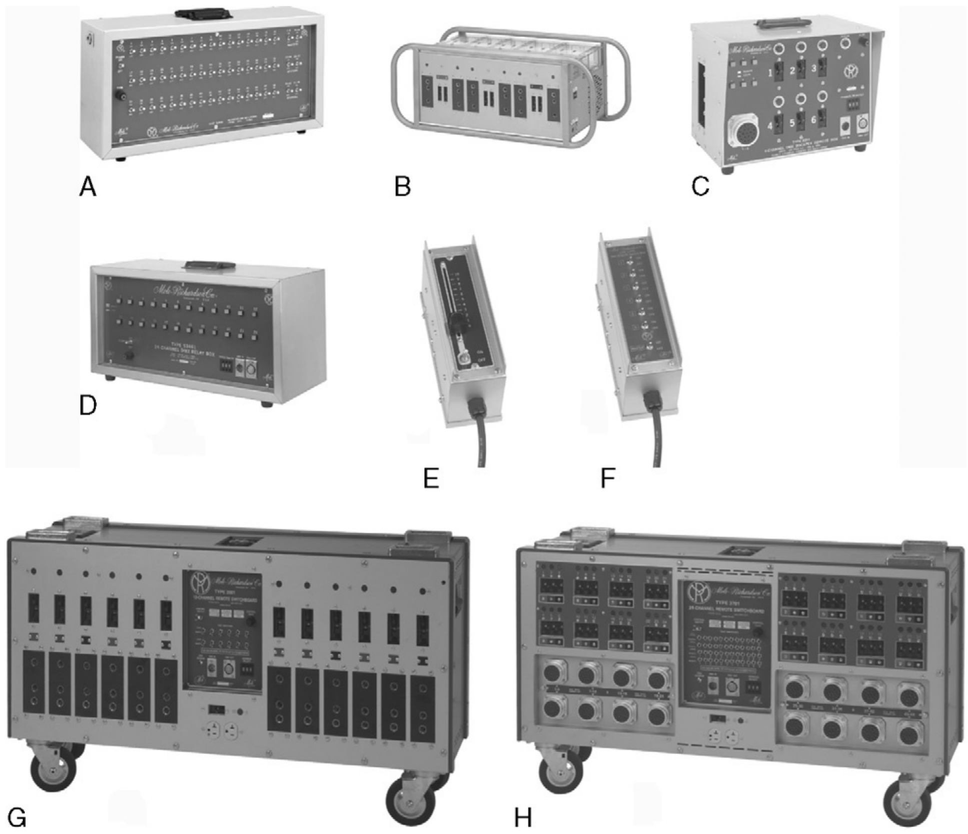


FIGURE 13.7

DMX512-controlled distribution boxes and accessories: (A) DMX switchbox, (B) DMX 600 A distribution box, (C) DMX Socapex lunch box, (D) relay box, (E) DMX remote slider, (F) six-channel DMX remote switch, (G) DMX 1200 A Remote Switchboard with twelve 100 A Stage Pin outlets, (H) DMX 800 A AC/DC Socapex Remote Switchboard with eight groups of six individually switchable 2.4k breakers, with two Socapex output connectors per group.

(Courtesy Mole-Richardson Co., Los Angeles, CA.)

Stage pin (Bates) connectors

In the United States, Stage Pin connectors are widely used connectors for lights. In Europe and Canada, stage pin connectors are not permitted. Stage Pin connectors can be traced back to the first pin connectors made for Kleigl Bros. in the 1920s. They are commonly called Bates connectors.[3]

[3]The Bates name has stuck from many years ago when Union Connector Company made the connectors for Bates Electric, a theatrical lighting company on Bates Street in L.A. Because all their equipment was identified with "Bates" written on the plugs, the connectors came to be known as Bates connectors. In the 1990s, Marinco bought the "Bates" name. Until then, it was not a trademark.

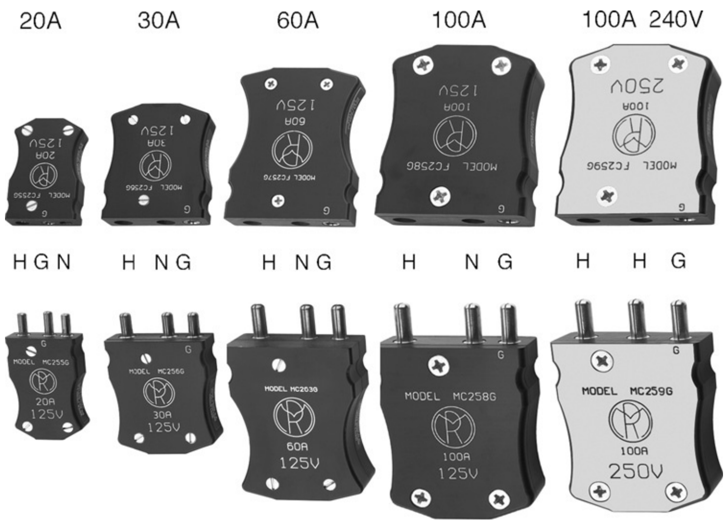


FIGURE 13.8

Pin configurations for Stage Pin connectors of various sizes. The 100 A 240 V connector is similar to the 100 A connector, but the center pin carries a phase instead of neutral. The center pin positioned closer to the center of the plug. The 240 V connectors are yellow.

(Courtesy of Mole-Richardson Co., Los Angeles, CA.)

They are also sometimes called *Union connectors* or *three-pin connectors*. Bates connectors come in several sizes: 20, 30, 60, 100 A (at 120 V), and 60 and 100 A (at 240 V) (Figure 13.8). The 120 V three-pin connectors are wired: hot wire, neutral, and ground. The 240 V connectors have a ground and two phase wires, no neutral.

Bates connectors are flat connectors so that they do not roll when stepped on; they do not stand much taller than the cable itself. The pins are sized and positioned asymmetrically so that they make ground first, break ground last, and they are polarized—they cannot be plugged in incorrectly. Most Bates are not locking connectors (although some manufacturers do make a locking type), so where one Bates cable plugs into another, tape the connection so that they don't pull apart (Figure 13.9), and/or tie the cables together using the cable ties (Locking connectors are only required on feeder cable).

The 100 and 60 A extensions (100, 50, or 25 ft.) run from the distro boxes to the lights and gang boxes. A 100-60 A adapter/splitter is used to connect 60 A plugs to the 100 A outlets when the distro box does not supply 60 A Bates outlets. Table 13.5 gives some examples of how Stage Pin connectors are typically used in motion picture and television.

Vendors who supply lights for theatrical and concert venues often supply ellipsoidal spotlights and PAR cans fitted with 20 A Stage Pin connectors. To be used with an Edison distribution system, these lights must be ordered with a "pigtail" adapter (Edison male/Bates female). Some television studios that do primarily in-studio productions rather than location work also use only Stage Pin connectors rather than Edison. Such facilities are typically installed with permanent Bates sockets with numbered circuits distributed around the stage, on the walls, in the floor, and mounted to overhead

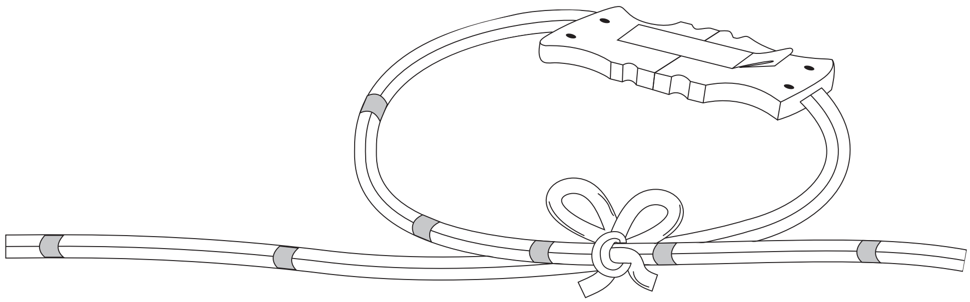


FIGURE 13.9

Bates connectors often need to be held together by tape or by making a loop and wrapping one of the cable ties around both cables.

Table 13.5 Common applications for stage pin connectors

Stage pin connector size	Typical light wattage range	Examples
20 A	0–2k	Ellipsoidal (Leco) 750 W, 1k Par cans up to 1k 1k and 2k Fresnels used in theaters or television studios (location lights use Edison plugs)
30 A	Not used in our segment of the industry	
60 A	2.4k–6k	2.4k HMI 4k softlights 4k HMI (120 V) 5k Fresnel 5k skypans 9-light FAYS (5850 W) 6k coops, 6k spacelights
100 A 120 V	6k–10k	8k softlights 9k Maxi-Brutes 10k Fresnels
100 A 240 V	4k–20k	4k (240 V) HMI 6k HMI 12/18k HMI 20k tungsten

pipes. This permanent feeder system is hardwired to a patch panel and dimmer systems. In this situation, 20 A Bates extensions are used instead of Edison stingers. If you are using a large number of Bates-fitted lamps, distro boxes with 20 A Bates outlets can be ordered, but ordinarily in motion picture work we use Edison outlets for lamps that are 2k or less.

Bates connectors are not made to a single industry standard. Two listed plugs from different manufacturers might fit tight mechanically but not make a good electrical connection. To check for a

good fit, insert the single hot pin into the female and check for snugness. Inspect the pin and sleeve. Look for discoloration due to overheating, burnt, pitted, or deteriorating pins due to arcing and signs of overheating inside the plug due to a weak connection to the cable.

Receptacle boxes

Lunch boxes and gang boxes

Edison outlet boxes are fitted with either a 100 or 60 A male Bates (Figure 13.10). A *lunch box* is a 100 A box that provides five 20 A duplex circuits (10 Edison outlets) with 20 A circuit breakers and indicator lights on each circuit. Alternately, boxes may be fitted with 20 A Bates or 20 A twist-lock outlets instead of duplex. Most also provide a 100 A female outlet so that you can feed through to subsequent boxes.

The duplex outlets on most Edison boxes are a heavy-duty type commonly known as *hospital-grade outlets*. They are designed for constant use, plugging and unplugging equipment. A normal household outlet would wear out. Hospital-grade outlets have a small green dot on the face of the outlet. Hospital-grade receptacles come in many colors—white, brown, blue, and red—but it is only the green dot that signifies hospital grade.

A variety of NEMA-rated plugs and sockets are shown in Figure 13.11. Note that the 5-15 plugs and sockets are rated for only 15 A. The 5-20 sockets are rated for 20 A.

A fused gang provides two to five fused duplex outlets. Each circuit has a separate 20 A fuse. Spring holders for spare fuses are mounted next to the fuses. These fuses blow from time to time. It is worthwhile to keep a couple of spares with you, so you can replace a bad one immediately and return the circuit to service.

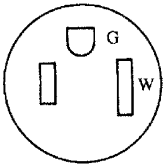
The advantages of breakers are that a tripped breaker is easy to find and breakers can be used to switch a circuit on and off (making it a lot easier to switch off a light that is hung out of reach). The disadvantages are that circuit breakers are more expensive and more delicate than fuses and can be tripped only a finite number of times before they need to be replaced, which drives up the maintenance costs for the rental house.

A B C

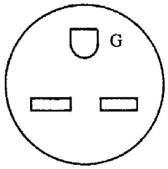
FIGURE 13.10

Edison boxes: (A) the classic 100 A lunch box with five duplex outlets, (B) a 60 A gang box with three 20 A duplex outlets, (C) a 100 A gang box with five single 20 A Edison outlets.

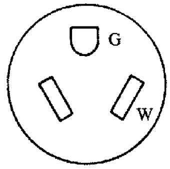
(Courtesy of Mole-Richardson Co., Los Angeles, CA.)



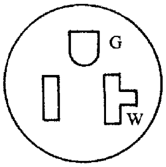
15 Amp 125 Volt Grounding
2 Pole 3 Wire
Standard for residential / commercial.
5-15 R (receptacle); 5-15 P (plug)



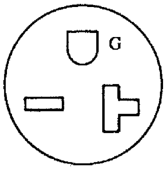
15 Amp 250 Volt Grounding
2 Pole 3 Wire
Room air-conditioners, heavy-duty tools.
6-15 R (receptacle); 6-15 P (plug)



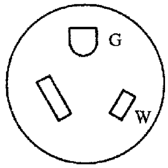
15 Amp 277 Volt Grounding
2 Pole 3 Wire
7-15 R (receptacle); 7-15 P (plug)



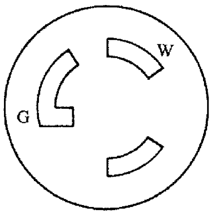
20 Amp 125 Volt Grounding
2 Pole 3 Wire
Room air-conditioners, heavy-duty tools.
5-20 R (receptacle); 5-20 P (plug)



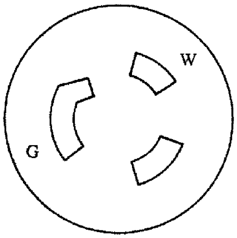
20 Amp 250 Volt Grounding
2 Pole 3 Wire
Room air-conditioners, heavy-duty tools.
6-20 R (receptacle); 6-20 P (plug)



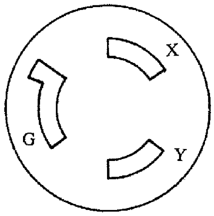
20 Amp 277 Volt Grounding
2 Pole 3 Wire
7-20 R (receptacle); 7-20 P (plug)



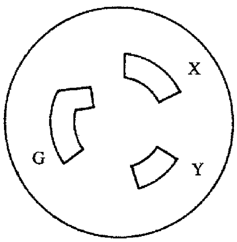
15 Amp 125 Volt Grounding
2 Pole 3 Wire
Common in older stages.
L5-15 R (receptacle); L5-15 P (plug)



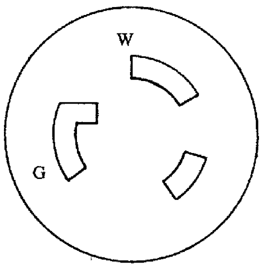
20 Amp 125 Volt Grounding
2 Pole 3 Wire
Standard for stage use.
L5-20 R (receptacle); L5-20 P (plug)



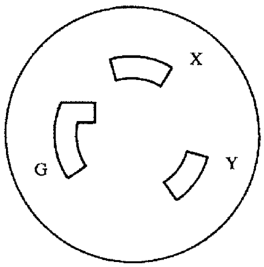
15 Amp 250 Volt Grounding
2 Pole 3 Wire
For special stage applications.
L6-15 R (receptacle); L6-15 P (plug)



20 Amp 250 Volt Grounding
2 Pole 3 Wire
For high voltage stage use:
heaters, fog barrels, etc.
L6-20 R (receptacle); L6-20 P (plug)



30 Amp 125 Volt Grounding
2 Pole 3 Wire
Not standard for stage use.
L5-30 R (receptacle); L5-30 P (plug)



30 Amp 250 Volt Grounding
2 Pole 3 Wire
Not standard for stage use.
L6-30 R (receptacle); L6-30 P (plug)

FIGURE 13.11

Edison and Twist-Loc NEMA-rated connectors.

(Reprinted with permission from Backstage Handbook *by Paul Carter, New York: Broadway Press, 1988.)*

240 V lunch boxes

For this discussion, when we say 240 V, we are talking about any service in that range—208, 230, or 240 V. Connectors used for voltages in this range are often rated at 250V. Many moving lights use 208 V power, and employ either a L6-20 (20 A, 250 V) or L6-30 connector (30 A, 250 V). Figure 13.11 shows the L6-20 connector and the L6-30 connector, which are commonly used on power cords for moving lights and followspots.

Power boxes for these outlets may use a 100 A/240 V Bates input as shown in Figure 13.12A, or may be fed with Socapex cable, which carries six separate circuits. Socapex cable is handy for this application, because it allows you to feed power to each of the moving lights separately, which allows you to perform a power reboot on an individual light from the ground.

FIGURE 13.12

208-240 V distribution: (A) 240 V 100 A Bates input, lunch box with four 240 V 30 A twist-lock outlets (NEMA L6-30); (B) Bates 100 A, 240 V input with Socapex (208-240 V) output; (C) moving light distro box with Cam-Lok inputs and multiples L6-20 and Socapex (208-240 V) output connectors. Similar distribution boxes

If you are using 2.5k and 4k 240 V HMI ballasts, you can use a L6-30 box (Figure 13.12A) to connect four 2500 or 4k 240 V ballasts. This eliminates a big mess of three-fers and adapters and allows four 4ks to run off a single 100 A/240 V extension cable. Each circuit is protected by a double-pole 25 A breaker. The ballasts require an adapter to a male L6-30 twist-lock. Double-check the power requirements of your HMI ballasts. Nonpower-factor-corrected ballasts and ballasts running on 208 V instead of 240 V may draw more than 25 A.

19-pin "Socapex" connectors and cable

Socapex cable,[4] also called *19-pin* or *multiconductor cable* or *Soco* for short, carries six separate 20 A circuits together in one multiconductor cable.

Socapex connectors are commonly found in the following applications:

- Dimmer racks and packs with 1.2, 1.8, and 2.4 kW dimmer circuits are often configured with Socapex outputs for direct connection to Socapex cable. Racks and packs that provide single-circuit outputs (usually 20 A Bates) can be fed into Soco cable by attaching a Soco *break-in adapter*. At the lamp end of the cable, a Soco *break-out adapter* separates the six numbered circuits, providing either Edison outlets or 20 A Bates outlets for the lights.
- Some six-circuit light fixtures, such as coops and space lights, use Soco input connectors, which provide individual control over each lamp in the fixture.
- Socapex distro boxes can be used to plug Soco lines directly into hard power (Figure 13.13). These boxes provide manual on/off control of the individual circuits, and some provide DMX512-controlled remote switches.

FIGURE 13.13

Socapex distribution: (A) 600 A MolePlex distribution box, Cam-Lok inputs. Four Socapex outputs with six individual 20 A breakers per outlet, six 20 A duplex. (Courtesy Mole-Richardson Co., Los Angeles, CA.) (B) Dadco Socapex distro box: Cam-Lok inputs, Cam-Lok flow-through, six six-circuit Socapex outputs with six individual 20 A breakers per Socapex, two 20 A courtesy outlets. (Courtesy Dadco.) (C) A Socapex break out adapter—Socapex male to six Edison female. (Courtesy Mole-Richardson Co., Los Angeles, CA.)

[4]Socapex is a trademarked name owned by Amphenol-Socapex, the original manufacturer. But other companies also manufacture 19-pin-compatible connectors, and refer to their products as Socapex.

- 208 V circuits commonly used to deliver power to a break-out adaptor (Soco to L6-20 connectors) to power 6 208 V moving light fixtures.

When lights are individually controlled on 20 A circuits, Socapex cable makes cabling much less cumbersome. It comes in long lengths to cut down on connection points: 200, 150, 100, 50, and 25 ft.

Rating Socapex cable

Multiconductor 19-pin connectors may have #12 AWG wires (rated for 20 A per circuit), or #14 AWG (rated at 15 A per circuit). Amphenol-Socapex specifies that the cable assembly is rated at 20 A, with #12 AWG conductors. However, experience has shown Socapex cable cannot handle a full load for long periods of time. This is aggravated by conductor degradation over time from physical abuse and heat. The crimp or solder points are not always in perfect condition. If you load up a piece of cable with six 2ks, the connectors and cable are going to heat up excessively. If these lights are left on for extended periods of time, especially in long runs, the results can be catastrophic. To ensure reliability, many rigging gaffers rate the cable at no more than 12.5 A (1500 W) or even 8.3 A (1000 W) per circuit if the lights are to be left on for extended periods (more than 3 hours) or the runs are long. Keep connectors and cable well ventilated. Avoid piling connectors or conductors on top of one another. Cables in contact with each other cause excessive heat buildup. Dimmers and distribution boxes with Socapex outputs often supply two parallel Socapex output connectors for each group of six circuits and use 20 A circuit protection for each circuit. This allows two 1k fixtures to be plugged to the same circuit, through separate Socapex cables, thereby avoiding putting a 2k load through one Socapex cable.

Socapex pin configuration and troubleshooting

The 19-pin connector is shown in Figure 13.14. Pins in the outer circle are the phase and neutral wires of the six circuits. Those in the inner circle are grounds for each circuit. The center pin, 19, is not used or may be used as an additional ground. If the cable used is 18 or 19 conductor cable,

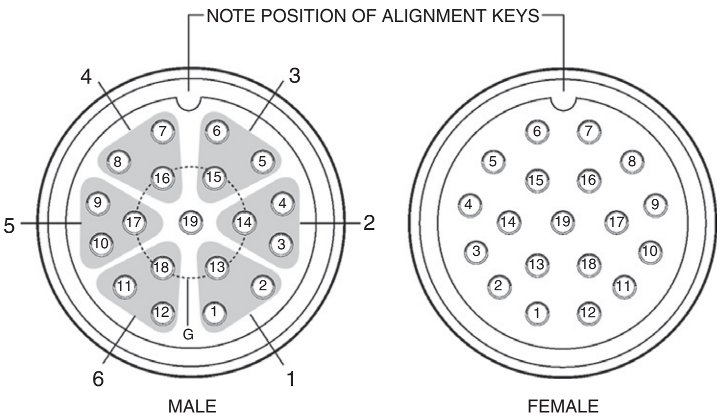


FIGURE 13.14

Each of the six circuits in a 19-pin Socapex cable has its own hot, neutral, and ground wires (shown here in gray). The proper position of the keyway and good condition of the pins are essential to proper function.

each circuit gets an individual ground wire. If used with 14-conductor cable, all the ground pins are bussed together.

Multiconductor connectors and cables are susceptible to damage that can result in shorts between conductors or breaks in a conductor. A Socapex tester like the one shown in Figure 13.15A is a very handy troubleshooting aid. Some distribution boxes come equipped with circuit indicator lights that also serve this function. Figure 13.15B and C shows 120 and 208 V indicator lights, respectively.

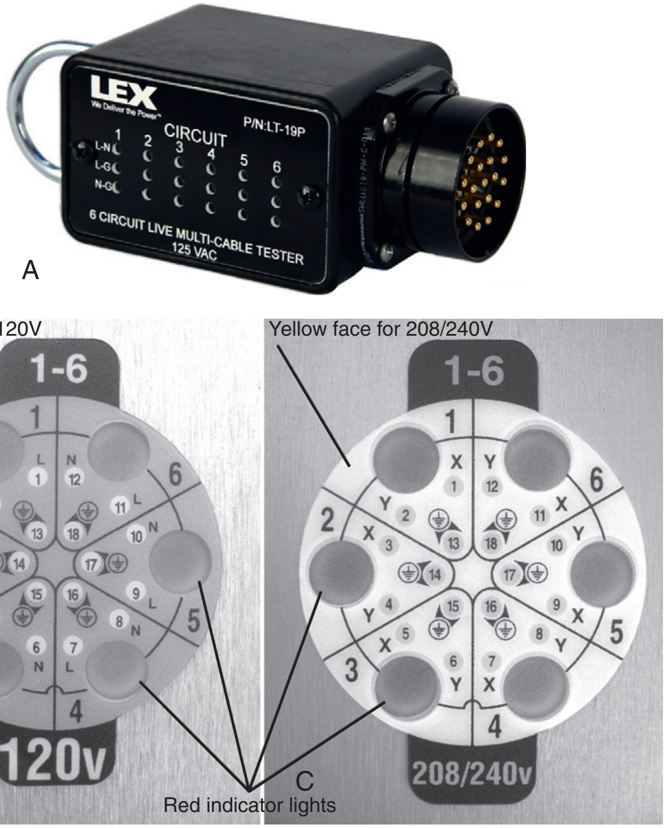


FIGURE 13.15

(A) LEX six-circuit live multicable tester plugs directly into a 120 V multiconductor cable. When the circuits are energized, green LEDs indicate the presence of voltage potential between LINE and NEUTRAL (L-N), yellow LEDs show voltage between LINE and GROUND (L-G), and red LEDS indicate voltage between GROUND and NEUTRAL (G-N). A correctly functioning cable will show green and yellow LEDs for all six circuits, but should not light any red LEDs. To check for cross-wiring, bring each circuit up to full separately. Note that the tester will give a positive result even if only one strand of wire is still making contact in the connector. (Courtesy Lex Products Corp.) (B) The six indicator lights on this distribution box show which circuits have power. The pins are labeled LINE (L), NEUTRAL (N), and GROUND. (C) A 208/240 V Socapex outlet indicator uses a yellow face color to distinguish it from a 120 V one. The pin labels X and Y indicate two phase wires. (B and C: courtesy AC Power Distribution, Inc.)

The male Soco connector has a key at the top to orient the connectors and a threaded collar that twists and pulls the connectors together, then click-locks with the female. A keeper inside the connector keeps the key properly oriented. If it breaks, the whole connector can spin and you can end up with the wrong dimmer number coming up. The key should always be located between pins 6 and 7 (as shown in Figure 13.14). When checking over cable before installation, be sure the connector's strain relief is tight. If the outer insulation has pulled out of the strain relief and you can see the inner wires, do not use the cable. When the strain relief is loose, the bare pins (male end) or receptacles (female end) start to pull out of the insulating housing into the connector. The wires can get pulled and twisted when the connector is handled—bad things can result.

Adapters

There are as many kinds of adapters as there are different combinations of connectors. When ordering equipment, the best boy must take care to order the adapter needed to connect each piece of equipment. When referring to an adapter, designate the male end first (for example, a Bates to Edison adapter has a male Bates and gives you a female Edison).

100 A to two 100 A splitters: The idea of this splitter is to give you more 100 A outlets. Of course the total amperage still can't exceed 100 A.

100 A to two 60 A splitters: Order as many of these as you have lights and Edison boxes with 60 A tails. Note: Some adapters are fitted with inline 60 A fuses. Be sure to stock spares and be on the lookout for burnouts.

240 V 100 A Bates snakebites (MoleLock or Cam-Lok to Bates adapters): If you get caught without a 240 V Bates outlet for a 20 kW or 12/18 kW, this adaptor solves the problem. As explained earlier, the circuit breaker on a 20 kW stand-alone dimmer or HMI ballast serves as branch overcurrent protection. This allows you to connect directly to a flow-through Cam-Lok connector or spider box in accordance with the 25 ft. rule.

Three-wire 100 A Bates snakebites (three-wire MoleLock or Cam-Lok to two 100 A Bates): In the absence of a distro box, a snakebite patches directly into three-fers. *Note*: although very handy, there is no overcurrent protection here.

Edison to 20 A Bates pigtails: You may need adapters with any theatrical lights you order.

100 A Bates to MoleLock or Cam-Lok adapters: Be sure to ask the type of connector for any large lights you order. If the light has Mole pins or Cam-Lok, you may need to adapt to 100 A Bates.

Socapex break-in and break-out adapters: A break-in adapter has six numbered male connectors (usually either 20 A Bates or Edison) leading to one female Socapex connector. They are used to channel power from separate circuits into a Socapex line. A break-out adapter is used at the load end of the Socapex cable to go from male Socapex to six numbered female connectors (20 A either Bates or Edison).

Jumpers: Lug to Cam-Lok jumpers are typically used to connect dimmer packs to a spider box. The 10-ft. jumpers are handy to connect deuce boards to a nearby spider box. Banded jumpers (MoleLock or Cam-Lok) are handy to wire a distro box into a spider box.

ELECTRONIC DIMMER SYSTEMS

Electronic dimmer systems were developed in the 1960s as a smaller, less cumbersome replacement for the large systems of autotransformers or resistance dimmers used in theaters at the time. Thanks largely to their widespread use in the concert touring industry in the 1970s, dimmer manufacturers adapted their systems for portable use. Dimmers are packaged in a variety of ways. Dimmer *packs* (Figure 13.16A) provide a small number of dimmers in a relatively small package. For larger dimming jobs, a touring *rack* combines multiple dimmer modules into a single compact rolling welded metal cabinet (Figure 13.16B). These are manufactured in a wide variety of configurations. Common ones are listed in Table 13.6.

Input power feeder connectors are Cam-Lok. The dimmer circuit outputs may be configured with Stage Pin (Bates) 20, 60, or 100 A, according to circuit size, or with Socapex outputs, Edison, or 20 A twist-lock connectors (specify when ordering).

Later in this section, we will discuss two dimmer systems that are widely used: Strand CD80 and ETC Sensor dimmer systems. Strand's CD80 packs are still being manufactured, although Strand stopped making the CD80 dimmers for touring racks and permanent dimmer installations in 2005, replacing the line with their C21 series dimmer system. Both the C21 system and ETC's

A B

FIGURE 13.16

(A) CD80 Digital Pack (courtesy Philips Strand Lighting); (B) ETC's Touring Sensor Dimmer Rack

(Reproduced by permission of Electronic Theater Controls, Inc.)

Table 13.6 Common dimmer configurations and power requirements (per phase)

		Amps Per Phase at 120/208 V Three-Phase (A)	Amps Per Phase at 120 V Single-Phase (A)
Strand CD80 Packs			
12	1.2 kW dimmers, 15 A circuits	60	90
24	1.2 kW dimmers, 15 A circuits	120	NA
12	2.4 kW dimmers, 20 A circuits	80	120
24	2.4 kW dimmers, 20 A circuits	160	NA
6	6 kW dimmers, 50 A circuits	100	150
6	12 kW dimmers, 100 A circuits	200	NA
1	20 kW dimmer, 240 V, 100 A	NA	NA
Strand CD80 Touring Racks			
48	2.4 kW dimmers, 20 A circuits	320	NA
96	2.4 kW dimmers, 20 A circuits	640	NA
24	6 kW dimmers, 50 A circuits	400	NA
24	12 kW dimmers, 100 A circuits	800	NA
ETC Sensor Packs			
12	1.8 kW dimmers, 15 A circuits	60	NA
24	1.8 kW dimmers, 15 A circuits	120	NA
12	2.4 kW dimmers, 20 A circuits	80	NA
24	2.4 kW dimmers, 20 A circuits	160	NA
6	6 kW dimmers, 50 A circuits	100	NA
12	6 kW dimmers, 50 A circuits	200	NA
3	12 kW dimmers, 100 A circuits	100	NA
6	12 kW dimmers, 100 A circuits	200	NA
ETC Sensor Touring Racks			
24	1.8 kW dimmers, 15 A circuits	120	NA
48	1.8 kW dimmers, 15 A circuits	240	NA
96	1.8 kW dimmers, 15 A circuits	480	NA
24	2.4 kW dimmers, 20 A circuits	160	NA
48	2.4 kW dimmers, 20 A circuits	320	NA
96	2.4 kW dimmers, 20 A circuits	640	NA
24	6 kW dimmers, 50 A circuits	400	NA
48	6 kW dimmers, 50 A circuits	800	NA
12	12 kW dimmers, 100 A circuits	400	NA
24	12 kW dimmers, 100 A circuits	800	NA

Notes:
(1) 15 and 20 A Sensor modules are available as dual dimmer modules (one or two dimmer circuits per module). This allows a rack with 48 module slots to house 96 15 or 20 A dimmer circuits.
(2) The power requirements column gives the maximum capacity of the rack (all dimmers loaded to their capacity). For your load calculations, you can use your actual load, if known.

Sensor+ system incorporate a modular design in which different ampacities of dimmer modules may be mixed within the dimmer rack. Both manufacturers make modules with a variety of rise-time parameters, as well as modules that provide sinewave dimming. Modules are also available that do not have a dimmer, but act as distribution circuits for non-dim loads. Contactor modules provide DMX512 on/off control, and constant modules provide circuit protection only (which are useful for powering automated lights). A dimmer with a longer rise time reduces audible buzzing from the lamp when dimmed. The advantages to each of these different options will become evident as we discuss dimmers more thoroughly.

In recent years, dimmer technology has advanced in a couple of important ways. Manufacturers have been able to design lighter, smaller more densely packed dimmer systems. The Strand LightRack and ETC SmartPack are examples of the new generation of touring systems ideal when a few dozen 10 and 20 A circuits are sufficient to cover your lighting needs. The Strand LightRack series use quieter, lighter, reverse-phase dimmers (explained shortly), and can also be fitted with 208 V constant power modules to serve as a distribution hub for moving lights. These mini racks are modular systems with interchangeable parts, so they can be configured to custom specifications for each show—ampacity and number of dimmers, type of modules, and type of output connector are all easily configured.

The other major advance is in communication protocols and equipment feedback. In film work, we tend to stick with simple DMX512 control; however, modern networked dimmer systems can provide greater convenience, functionality and system monitoring. Manufacturers have developed various proprietary protocols that work with compatible controller consoles (e.g., Strand's ShowNet and ETC's ETCNet2 and ETCNet3). In 2006, ESTA's Technical Standards Program published the first standards covering networked control protocols titled Architecture for Control Networks (ACN). ACN will be adopted even more widely in the future. The primary advantage of a networked dimmer system is two-way communication between the control console and the dimmer room. The console operator can call up a read-out of important information about each rack, and each dimmer including ambient temperature, rack address, voltage and frequency, dimmer load, and a wide range of other diagnostic data. The console operator can also change the settings without having to go to the dimmer room to do it. Some dimmer systems have adopted RDM.

Electronic dimmer circuit designs

For many years, entertainment industries have used forward-phase control electronic dimmers, commonly known as SCR dimmers, and these represent by far the greatest percentage of available equipment. Though this has been the dominant technology since the 1960s, there are actually three distinct types of dimmer circuits currently available: SCR (forward-phase control), reverse-phase control, and sinewave dimmers. Because SCR dimmers are so prevalent (and economical), they dominate the Motion Picture and Television market. Nonetheless, reverse-phase control and sinewave dimming each provide certain advantages. Reverse-phase dimmers are lighter and smaller than SCR types, and under the right circumstances may reduce lamp noise. Sinewave dimmers produce no lamp noise under any circumstances and also completely eliminate the problem of current harmonics and excessive current returning on the neutral conductor, which is a problem associated with both forward and reverse-phase control. We'll begin the discussion of dimmers by looking at how each of these circuits works, and the pros and cons of each.

Forward-phase control dimmers—SCR

Forward-phase control dimmers use a very simple, reliable device called a *solid-state relay* (SSR) that is made up of a pair of *silicon-controlled rectifiers* (SCR) to regulate power. An SCR is a type of *thyristor* (a solid-state latching relay) that conducts electricity in one direction only. By connecting two SCRs in parallel but in opposite directions in a circuit, one can make a solid-state device that regulates alternating current in both directions. Rather than increasing or decreasing voltage (the *amplitude* of the AC sinewave) as with a variable transformer, an SCR dimmer increases and decreases power by regulating the *duty cycle*, the on/off time, chopping up the sinewave as shown in Figure 13.17. The brains of the dimmer, the controller card, detects the incoming control signal (DMX512 or Ethernet), decodes it, and produces *pulse-width modulated* signals in sync with the dimmer's power phase to tell each SSR when to activate. Thus, during each half cycle of the AC sinewave, the dimmer controls output by varying how long the dimmer waits before it activates. The circuit automatically deactivates each time the wave passes through zero. This is known as *forward-phase control* dimming.

Forward-phase control is fairly simple and very reliable, and is an effective way to dim incandescent lights. Dimmers are commonly available with capacities of 1.2k all the way up to 12 kW at 120 V, and 24 kW at 240 V. *Because the sinewave is chopped up, phase control dimmers cannot be used on line with HMI fixtures or electric motors (such as motorized stands and fans). Using forward-phase electronic dimmers with such loads can cause damage to the load.*

The disadvantages to phase control dimmer technology are as follows:

- Phase control dimmers are *nonlinear* loads (the current is not in proportion to the voltage), because when dimmed, they draw current during only part of each line cycle. This creates harmonic distortion of the mains current. These harmonic currents add up on the neutral conductor. The neutral conductor may have to carry as much as 1.3 times the phase current even when the loads are equally distributed between phases. To carry the additional current, the neutral conductor size must be increased on the feeder cable and the power source (see Chapter 14). Typically, the generator or transformer must be oversized, or an appropriately K-rated transformer must be used (see Chapter 16).

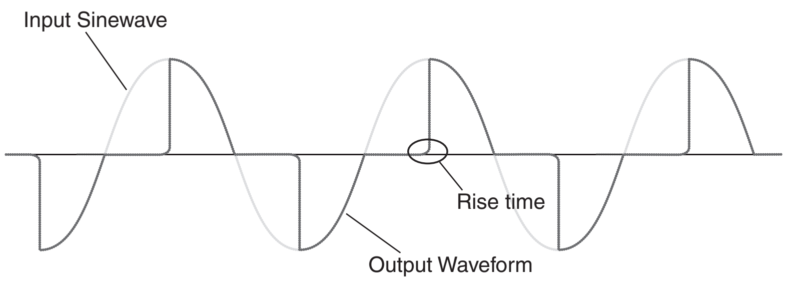


FIGURE 13.17

Forward-phase dimming regulates power by varying the duty cycle. At 50% power, the circuit remains off during the rise in the sinewave, then switches on at the peak of the wave.

- The on/off switching of the SCRs creates vibrations in the lamp, which produces buzz or "sing" when dimmed. This noise is worst at 33% and 66% intensity. Dimmers use toroidal filters (doughnut-shaped coils) commonly called *chokes*, which round-off the abrupt rise of voltage and inrush of current with each half cycle. The bigger the choke, the longer the rise-time and the less "sing." Phase control dimmers with 800 μs rise time are significantly quieter than those with 350 μs rise time; however, lamp noise is not eliminated.
- The vibration also reduces lamp life.
- The chokes cause heat losses that result in a typical SCR efficiency of about 95%. The chokes also account for a lot of the weight of a dimmer.
- With very small-filament lamps, phase control dimming at 60 Hz can cause flicker at certain frame rates and dimmer settings.

Most of the time, SCRs do not cause flicker, because the glow of filament in the lamp does not have time to decay appreciably between half cycles. However, when using very small lamps at very low dimmer settings and filming off-speed, you *can have flicker register on film*, just as you would with HMIs using magnetic ballasts. A friend of mine was filming a large sign fitted with hundreds of tiny 100 W bulbs. The sign was patched into the SCR dimmer system and was set at 35%. For normal filming (24 fps), this was fine; however, when the camera was set to 48 fps and the shutter angle set to 90° (giving an effective shutter speed of 1/96 of a second, which is not a flicker-free speed), the lights flickered on film. The main ingredient to this snafu was the small size of the lamp filaments. The smaller the filament, the more quickly it responds to changes in voltage. Lamps with larger filaments do not cause this problem. In this case, if variac dimmers had been used instead of SCR dimmers, if the dimmer setting had been higher, or if the camera had run at 40 or 60 fps (which are flicker-free speeds), the lights would not have flickered on film.

Reverse-phase control dimmers

An idea, introduced in 1992 by Entertainment Technology, to reduce lamp and dimmer noise is commonly called *IGBT dimming*. An IGBT (Insulated Gate Bipolar Transistor) is a type of high speed switch device, developed in the 1980s, that is used in power electronics. The idea is to employ IGBTs to perform *reverse-phase control* which will reduce the high inrush current that causes lamps and dimmers to vibrate. This is the same idea as forward-phase control, except that instead of chopping the front of the sinewave (using SCRs); IGBT dimming chops the back (Figure 13.18). This way the current rises smoothly up to the cutoff point. This eliminates the need for chokes, making the dimmer smaller and lighter, with around 3 V less voltage drop, and reduces the lamp noise. The rise time or fall time used by an IGBT dimmer can be varied by the electronics, and is often automatically reduced to counteract a rise in dimmer temperature. Thus, lamp noise may increase if the dimmer temperature increases. IGBT dimmer harmonics and excessive neutral current are about the same as forward-phase control dimmers.

The likelihood of recording flicker is the same as with forward-phase dimmers (when filming at nonstandard camera speeds and low dimmer settings using small-filament lamps). Strand Lighting (LightPack and LightRack) and Entertainment Technologies make IGBT dimmer packs and dimmer strips in 1.2 and 2.4 kW sizes as well as small stand-alone devices. IGBT dimmers cost about the same as SCR dimmers.

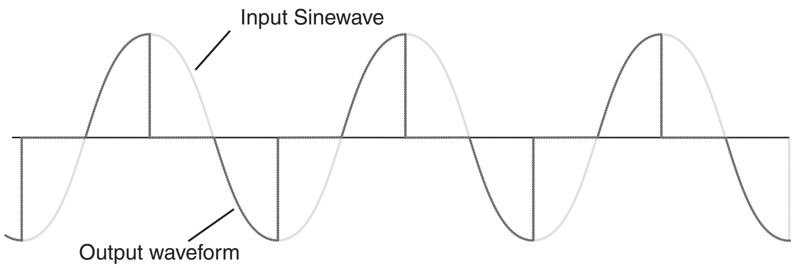


FIGURE 13.18

Reverse-phase control dimmer waveform at 50% intensity.

A dimmer like the Bak Pak dimmer (Intelligent Power Systems), or Strand Light Pack has some good applications in film work. The small stand-alone 750 or 1200 W IGBT dimmer can be set to either forward-phase or reverse-phase dimming. It is completely silent, so it can be used on set, hung on the light stand and used close to actors, with no sound issues from the lamp or the dimmer. Figure 13.19 shows the many features these flexible little devices incorporate, including: DMX512 control of dimmer, DMX512 control of flicker effects, dimming and flicker effects without any DMX512 control, rise time, and so on. You can also create coordinated effects between multiple Bak Pak units using one Bak Pak unit as a DMX512 transmitter by adding a small accessory called an Intelligent Effects Network Coupler.

Sinewave dimmers

At this writing, sinewave dimmers are available in North America for permanent installations only, not in portable rack or pack versions. The Strand SST Series is available in 1.2 and 2.4 kW, and the ETC Sensor Sinewave in 2.4 kW. Larger sizes are available in Europe. Currently, sinewave dimmers are available at a purchase cost roughly three times that of SCR phase control dimmers. Sinewave dimming is not currently used in motion picture and television applications, and may not ever be. Nonetheless, I include it here because it is an important technology that has the potential to offer some real benefits for our industry in the future, and it is interesting to learn how it works.

In contrast to phase control dimmers, sinewave dimmers produce a *full sinewave*. It is essentially an electronic version of the old autotransformer or variac dimmer. A sinewave dimmer varies the RMS voltage seen by the lamp using an IGBT circuit that operates at a very high speed (in the order of 47-50 kHz). The amplitude of the resulting RMS voltage is controlled using pulse wave modulation (PWM) within this very narrow time frame, 1/50,000th of a second, as represented in Figure 13.20. At 100%, the IGBT is on for the whole 1/50,000th of a second; at 50%, the IGBT turns off for half that time. The IGBT is turning on and off the full voltage; however, because the period is so short, and because circuitry is included to smooth the waveform, the load sees a continuous sinewave. This *completely* eliminates the problem of lamp noise.

Because power is drawn during the entire cycle, a sinewave dimmer does not create current harmonics. The resultant sinewave has less than 1% harmonic distortion. There is no need for oversized

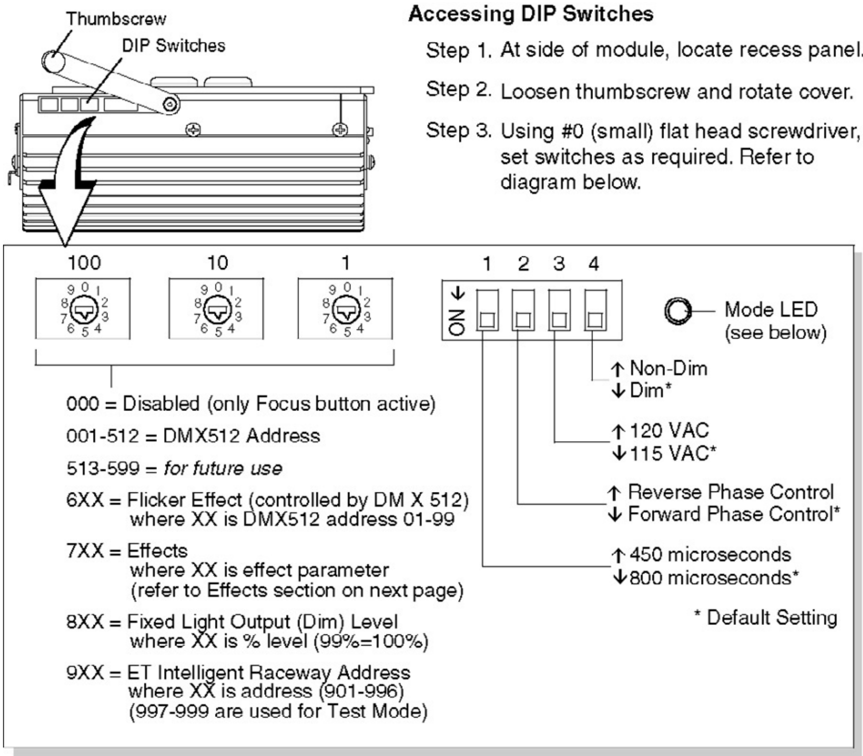


FIGURE 13.19

Bak Pak IGBT dimmer, also branded as Strand Light Pack dimmer. The three-digit address you enter determines the functionality of the dimmer. Entering 000 allows local control via the "focus" button located at the bottom of the unit. Hold the "focus" button down to run the level up or down. The Mode LED indicates the mode entered, and the presence of a DMX512 signal by blinking in one of several patterns (see operation manual).

(Courtesy Philips Entertainment Technology.)

neutral conductors or K-rated transformers. Sinewave dimmers have unity power factor (100%). A sinewave dimmer is said to be "transparent" to the load. It is able to deliver power to the load almost as if the load had a direct connection to the power line. This allows it to control most loads that SCR dimmers cannot, such as neon, cold cathode, LEDs, fans, and small motors.

The primary disadvantage to sinewave dimmers is that they are far more complex: an SCR dimmer comprises about six electronic components, whereas a sinewave dimmer comprises several hundred. The higher component count necessarily increases the chance of a part failing, thus decreasing comparative reliability. Sinewave dimmers require their power-handling components to be kept cooler than those of phase-control SCR dimmers, dictating larger cooling systems. So although the lights are quiet, the dimmers themselves are not, so the dimmers still must remain in an acoustically isolated and properly ventilated room.

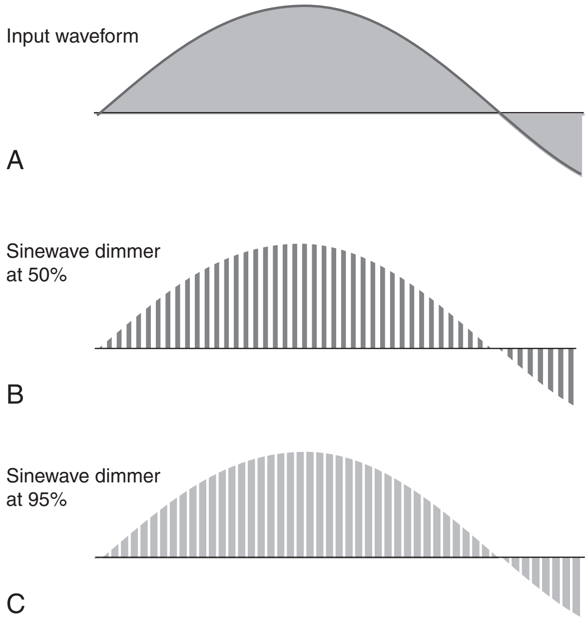


FIGURE 13.20

Sinewave dimmers divide the input sinewave (A) into very short periods and then control the duty cycle within those very short periods. When the duty cycle is set to 50% (B), the resulting output voltage waveform delivers half the input voltage. With the duty cycle set to 95% (C), the resulting output is 95% of full power.

Strand CD80 dimmer packs

Two of the most commonly used dimmer systems for motion picture and television applications are the Strand CD80 series of products and the ETC Sensor series. Dimmer manufacturers provide operation manuals and all kinds of other information about their equipment online. It is a good idea to download the information for the model you are using so that you have setup and troubleshooting information right at hand.

Installation and setup

CD80 packs (Figure 13.21) must receive adequate ventilation and be kept below 104 °F and no more than 80% humidity with no condensation. If the heat sink exceeds its temperature limit, it will shut down automatically. The CD80 packs are about 95% efficient; that means that 5% of the power has to be dissipated as heat. As many as eight packs may be stacked vertically. Do not place more than two units side by side unless there is at least 24 in. between packs. Otherwise, the exhaust heat from one pack is blown directly into the intake vent of the next pack. The packs are not designed to be used outdoors. Keep vents clear from obstruction, dirt, fibers, paint particles, and so forth. Sometimes it is convenient to mount the pack vertically on the wall. Orient the pack so the intake vent is at the bottom. Heat from the dimmer creates a chimney effect; you want the intake at the bottom and the outlet vent at the top; otherwise, the fans are fighting the natural airflow.

Ideally, the rack is mounted in a special air-conditioned, soundproof room, which eliminates the problems of both cooling and noise. When a large number of dimmers are used, we often build a shack outside the sound stage to house them. The shack protects the dimmers from sun and rain. It provides a floor that is raised above grade level. It has windows or vents in several walls to allow air to circulate through the shack. Air-conditioning units are installed to force air circulation. It is a good idea to monitor the room temperature with a thermometer in the dimmer shack.

The brains of the CD80 pack is the *digital pack controller* commonly known as the *card*. The digital controller comprises a faceplate mounted on a control card. The control card slides into slots in the front panel of the dimmer pack. Two thumbscrews secure it in place (Figure 13.21 and 13.22).

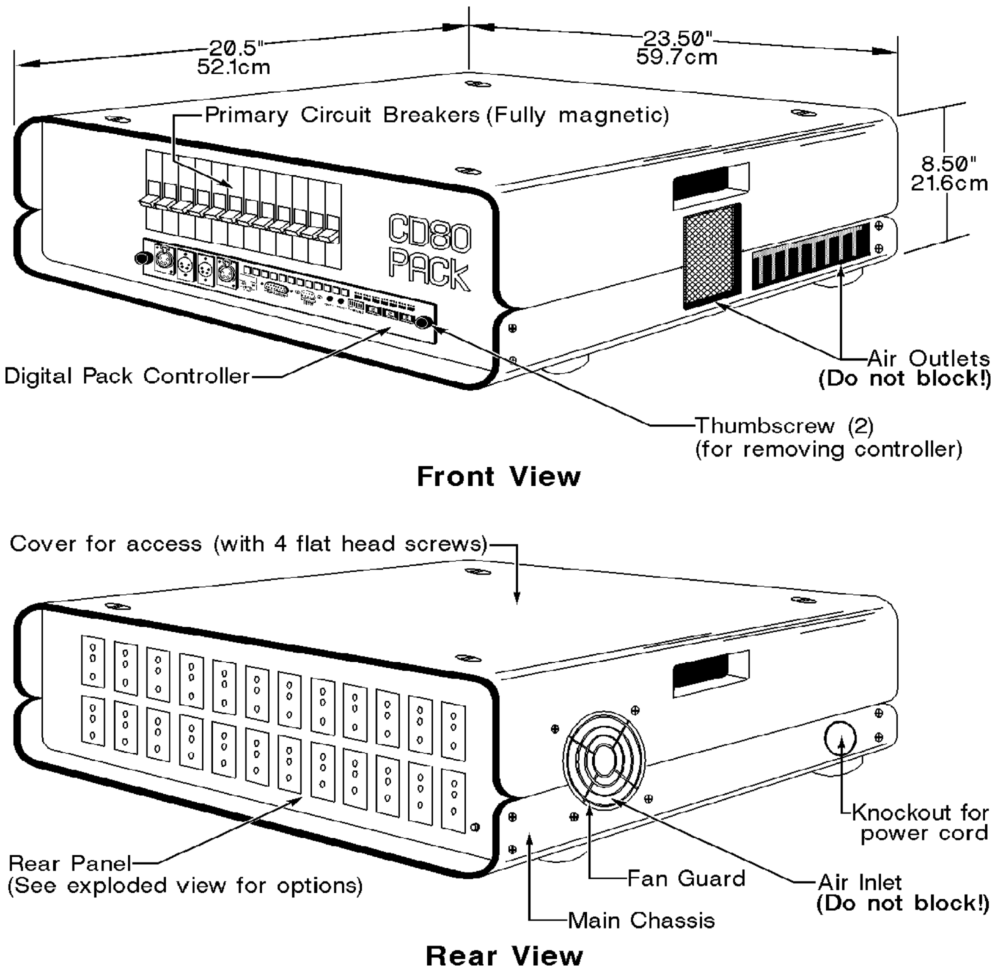


FIGURE 13.21

CD80 Digital Pack.

(Courtesy Philips Strand Lighting.)

In case of failure, the entire card can be replaced in the field. With the input power turned off, the digital pack controller can be removed and installed without disconnecting any wiring. Loosen the thumbscrews and pull on the thumbscrews to slide the controller straight out of the pack.

To install the controller (again, power off at source), line the controller up with guides on each side of the slot and slide the module in carefully until it touches the connector in the pack. Firmly set the controller by pressing on both ends of the module. Tighten in place with thumbscrews.

The faceplate contains the connectors, buttons, and indicator lights that affect everything the dimmer pack does (Figure 13.22). Later models of the CD80 use a digital control card with a menu-style interface, but perform all the same settings as the original.

- Input and output connectors for AMX-192 control cable (four-pin XLR). AMX-192 is obsolete.
- Input and output connectors for DMX512 control cables (five-pin XLR).
- Input connectors for 12 or 24 discrete analog control signals on a multipin connector. Analog is sometimes used in theaters to control house lights. It is not used for our work.
- Three power indicator lights (green) that show each input power phase present (ϕA, ϕB, ϕC). Use these to check the input power lines.

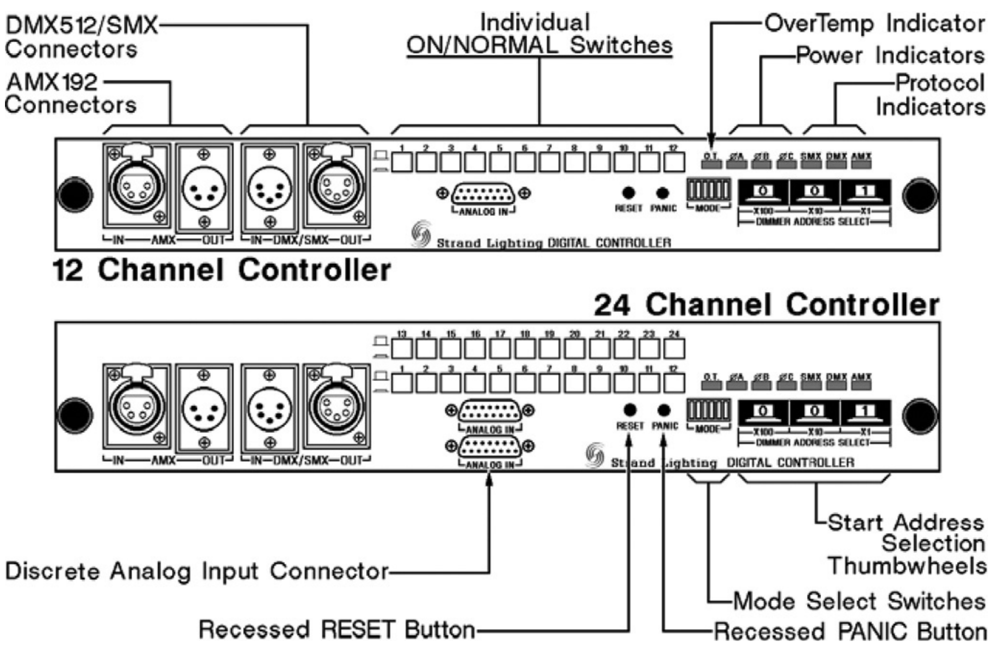


FIGURE 13.22

CD80 Digital Pack controller card.

(Courtesy Philips Strand Lighting.)

Table 13.7 Dimmer controller card dip switch settings

Position 1	Off: No effect
	On: No effect
Position 2	Off: Three phase
	On: Single phase
Position 3	When using analog and multiplexed protocol simultaneously, this switch determines if the output signal to the dimmer is the *sum* of the two signals (up to 100%) or the *higher* of the two signals (pile-on).
	Off: Highest takes precedence (pile-on)
	On: Dimmer level is analog + protocol
Position 4	Off: 0–15-V DC input level for analog input
	On: 0–10-V DC input level for analog input
Position 5	Off: In the event of loss of control signal, the dimmers retain current levels for 30 minutes
	On: In the event of loss of control signal, the dimmers black out
Position 6	Off: Uses every *other* control signal, starting with the thumbwheel number (use with 6-kW and 12-kW dimmers when using Strand lighting systems AMX 192 where 6-kW/12-kW dimmer assignment is made in the control console)
	On: Uses the first 12 control signals starting with the thumbwheel number

Notes: I underlined the setting that you typically want. Press the reset button to enter changes during operation. The control board reads these settings only during start-up. Changing them while in operation does nothing in most cases, until you press reset.

- Three protocol indicator lights (yellow), which show the protocol currently being decoded (AMX-192, DMX512, or analog).
- Six mode-select dip switches, used to set various important parameters of operation. Table 13.7 outlines the function of each of these six dipswitches. Be especially sure that switches 2 and 6 are set correctly or the dimmer pack may not work properly. If you change dipswitch settings during operation, press the reset button to enter changes.
- Over-temperature indicator light (red)—the dimmer pack shuts down automatically and this light comes on if the heat sink temperature exceeds 85 °C. This would happen if the vents were blocked, if ventilation were inadequate, or if the fan motor failed.
- Three numbered thumbwheels used to assign the start address for the dimmer pack. Addressing is also discussed in Chapter 11. Set the thumbwheels to the first dimmer number to which this dimmer pack is to respond. The digital controller will start looking at dimmer signals starting at the address on the thumbwheel.
- Recessed “panic” button. When pressed, this button turns all dimmers on. Push it again to return dimmers to normal operation. Use a bent paperclip or other small probe to get to the recessed button.
- Recessed reset button. When pressed, this button tells the card’s processor to restart.
- 6, 12, or 24 two-position circuit test pushbuttons. When set to the IN position, each button turns on the associated dimmer to full and overrides the control signal or operates the dimmer in the absence of a control signal. When the button is in the OUT position, the dimmer operates normally and the backlit button shows the approximate level of the associated dimmer.

Three small (0.250 A fast-blow) phase fuses are located on the controller card. If a phase B or C fuse blows, the dimmers connected to that phase will not function. If the phase A fuse blows, the controller is completely disabled. Replacing the fuses requires no special tools or procedures. With input power turned off, remove the controller card from the pack, replace the faulty fuse, and carefully reinsert the controller module.

The *dimmer law* refers to the response of the dimmer to the control signal over the range of fader settings. A direct one-to-one relationship between the control signal and dimmer output gives a fairly abrupt rise in light level as the fader is increased, whereas a modified square law gives smoother control over the lower end of the dimming curve. The default setting for this jumper is "modified square law." Normally you would change this only if you need to match the output curve of an analog or multiplexed analog (AMX) signal, when using both types of control signals. Dimmer law selection is made using the jumper on the control board, as shown in Figure 13.23.

In addition to the mode-select switch in position 2 (setting for single- or three-phase), 1.2, 2.4, and 6 kW packs have an interior single/three-phase selection plug on the power terminal block. The factory default setting is three-phase. To check the setting, remove the top cover of the pack and check the position of the phase selection plug shown in Figure 13.24. Close the pack and connect the input leads. Check the green power indicator lights to confirm that proper phases are powered.

Troubleshooting

Problems affecting the entire pack

No phase LED lit:

- No power to the dimmer pack. Check distribution and cable connectors.
- Controller may not be seated correctly. Remove and reinstall the controller.
- Fuse F1 (phase A) may be open (blown). Replace as discussed previously.
- If the fuses are okay and you can turn the dimmers on with their individual pushbuttons, the controller module is defective. Replace it with a spare and return it to the owner or Stand Lighting for repair.

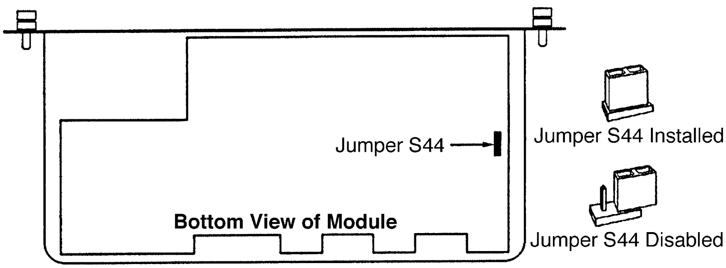


FIGURE 13.23

CD80 dimmer law jumper.

(Courtesy Philips Strand Lighting.)

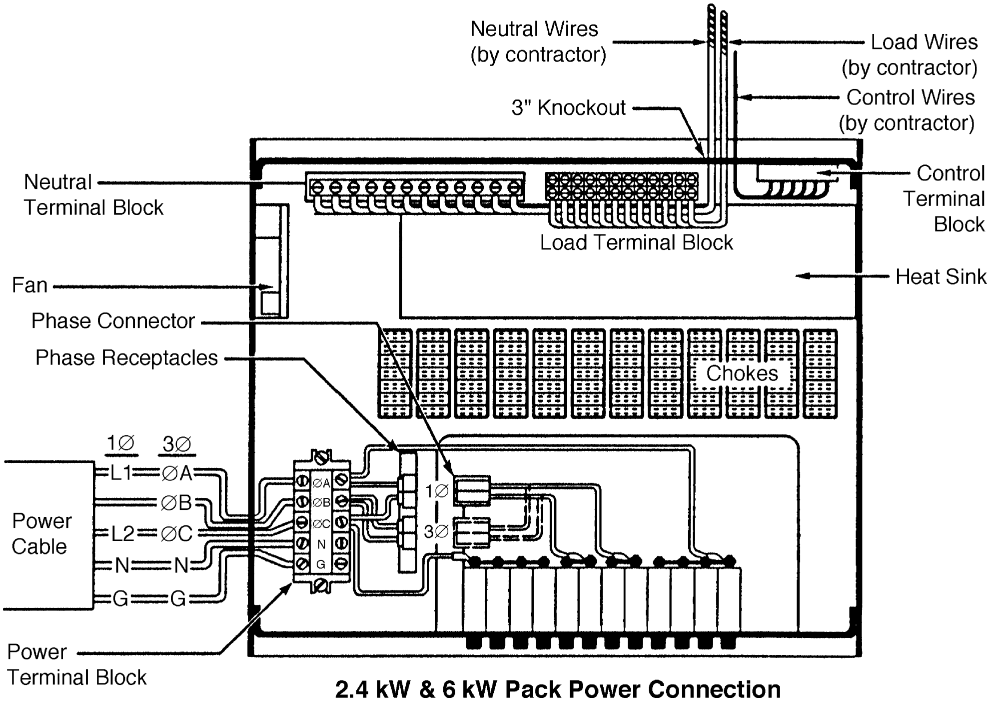


FIGURE 13.24

Phase selection plug.

(Courtesy Philips Strand Lighting.)

Phase B or C LED not lit:

- Fuse F2 or F3 is probably open. Replace the fuse (discussed previously).

All phase LEDs lit but no protocol indication:

- Check for incoming control signal using a DMX512 tester (see Chapter 11). Control console is unplugged or control cable is disconnected.
- Incoming control wiring may be miswired or one or more conductors broken.
- Replace control cable or check its continuity and wiring.

No control of dimmers (dimmers are always OFF):

- If the overtemp light is on, the pack has shut down from overheating. Make sure that the air intake and exhaust ports are not blocked and wait for the thermostat to reset.
- The thumbwheel settings may be set to an incorrect address. Double-check your settings.

No control of dimmers (dimmers are always on):

- The “panic” button may be on or the individual dimmer pushbuttons may be on.

Problems confined to one phase

Problems that are confined to one phase are usually related to controller problems or to the dimmer pack being incorrectly set up for the type of power in use.

Consecutively numbered dimmers will not go on:

- One phase of the power feeding the pack is off or not connected (for example, on a 12-dimmer pack, phase A powers dimmers 1-4, phase B powers dimmers 5-8, and phase C powers dimmers 9-12).
- The controller module may be incorrectly inserted. Remove it and carefully reinsert it into the dimmer pack.
- One or more output control circuits (in the controller card) have failed. Swap the controller card with a known good spare. If the problem goes away, return the defective controller for repair.

One or more dimmers on the same phase do not come up to full or do not track correctly:

- The mode-select switch (in position 2) may be incorrectly set. Make sure the pack is set up for the type of power being used.
- The phase fuse may be open.
- One or more output control circuits (or the controller) may be defective. Replace the controller with a spare and return the defective card for repair.

Problem with individual dimmers

Check the following:

- Dimmer circuit breaker on.
- Load wiring and lamp operating properly (not burnt out). Check the load wiring and lamp by turning on the pushbutton switch for that dimmer circuit. If nothing comes on, the problem is in the wiring or the lamp itself.

If you still have a problem, it is either a defective controller, defective discrete analog control wiring, or a defective SSR, circuit breaker, or choke. Each of these parts is designed to be easily replaced in the field. But of course this takes time and may involve moving the packs around in order to get to the affected pack.

- Check the controller module by replacing it with a known good spare. Make sure the mode-select switches are set the same way on the replacement controller. If the problem goes away with the new controller, return the defective controller for repair.
- Check for defective SSR, choke, or circuit breaker by checking the voltage at the circuit breaker output, choke output, and SSR output with the dimmer on. The component with an input but no output is defective (most commonly the SSR). Replace the defective component.
- If the dimmers flicker when at 50%, the control card is defective. Replace it.

Periodic maintenance

Strand recommends periodic maintenance every 6-12 months. Maintenance may or may not actually ever be performed by the rental house. Strand recommends consulting with a Strand field service technician to learn more about maintenance procedures. The short list includes:

- Power disconnected. Open the pack.
- Inspect for loose connections between components inside the pack.
- Vacuum out any dust buildup.
- Remove the control module, dust it off using a soft natural bristle brush, and clean the edge connectors with a mixture of 70% denatured alcohol and 30% distilled water, or other cleaning compound intended for gold edge connectors.
- Reinstall the power module and close the cabinet.
- Connect power to the pack. Connect a load to the dimmer outputs.
- Exercise each of the circuit breakers by turning them on and off several times while under load (the arc produced when the circuit breaker engages and disengages cleans corrosion and dust off the contacts).
- Connect control cable and verify proper dimmer function.

ETC Sensor dimmer system

The Sensor series is a modular dimmer system (Figure 13.16B). Dimmer modules (Figure 13.25) can slide into and out of the rack, and once fully inserted all power and control connections are automatically made. If a module starts to act up, it can be replaced easily with a spare without opening or disassembling anything.

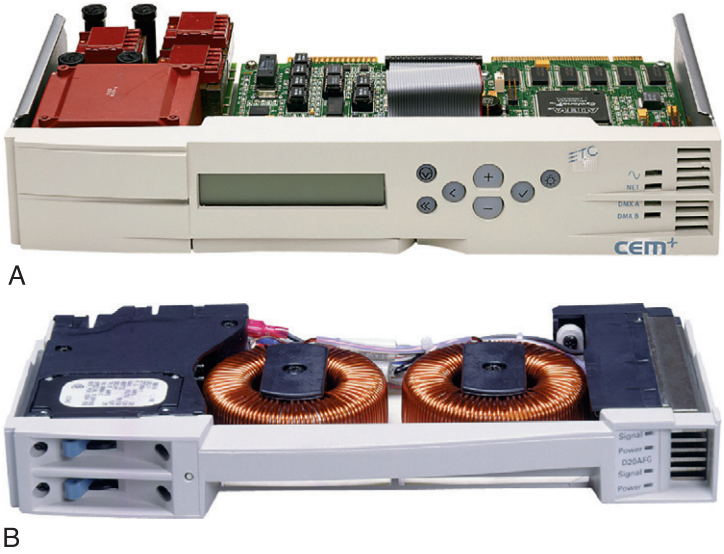


FIGURE 13.25

Sensor racks use a system of interchangeable dimmer modules: (A) Control Electronics Module (CEM), the brains of the Sensor Rack, (B) Class A GFCI Dimmer module (this module contains a pair of dimmers. Note the pair of circuit breakers. The two big windings are the choke coils).

(Reproduced by permission of Electronic Theater Controls, Inc.)

To remove a module:

1. Turn the module circuit breakers off.
2. Press on the module retainer if installed (left side of module) to retract it.
3. Grasp the metal lip that extends from the face panel and gently pull the dimmer module out.

Each module has an LED marked “Signal” that will be on whenever the dimmer output is on. Sensor Advanced Feature (AF) modules have a second LED labeled “Output.” The Output LED is on any time the dimmer output is above zero. ETC makes a number of different types of modules that can be used in any compatible Sensor rack or pack:

Standard modules	Provides 100% constant use, fully magnetic circuit breakers. The rise time is either 350, or 500 μs depending on the model.
High rise time module	High rise time modules reduce filament buzz by using a longer rise time than standard modules. The rise time is 800 μs.
Advanced feature module	AF dimmers are designed to be used in Sensor+ enclosures. They incorporate an output voltage and current sensor in order to provide feedback to the control console about the dimmer and load circuit via an Ethernet-based protocol—either ETCNet2 or ETCNet3 (ACN). The rise time is 500 μs.
Fluorescent dimmer module	To control particular kinds of fluorescent circuits.
Relay module	On/off switch circuits (15 and 20 A modules only). Power for motors, moving lights, and ballasts.
GFCI dimmers	Dimmers with Class A GFCI overcurrent protection (15 and 20 A modules only).
Constant current CB module	Provides 100% constant use, fully magnetic circuit breakers with no control electronics (15 and 20 A modules only). The circuits can only be switched ON and OFF at the circuit breakers, and not remotely. This type of module is used when you want to power a load through the same distribution system but it is not one that you would want to allow to be accidentally switched OFF—“hard power.”

The design of the ventilation requires that all module slots be filled when running. An *airflow module* is a blank that covers any unused slots to provide proper airflow. Space for spare modules is provided on the right side of the rack at the bottom. Spare modules do not automatically come with the rack; you have to order them.

The Control Electronics Module (CEM) is positioned at the very top of the stack of dimmer modules on the touring racks. The CEM contains all the control electronics. This is where the DMX start address is set as well as all the other setup options and features. There are several generations of Sensor racks in use: CEM, CEM+, versions 1.0, 2.0, and 3.0. The biggest change in each of these iterations is the Ethernet control. The original CEM incorporated DMX512 and ETCLink. The CEM+ V1.0 introduced ECTNet2. Version 3.0 introduced ACN. All versions also have DMX512 inputs. A detailed description is beyond the scope of this book (and easily obtainable online). The capabilities available with each CEM generation has grown. The CEM can memorize and playback up to 32 user-programmable backup looks. It can bypass the dimmer electronics to make circuit/lamp tests. It provides five selectable dimmer law output curves. The CEM has three-phase LEDs and an error LED as well as an LCD display that can present helpful information like:

Rack:	voltage, frequency, start address, DMX512 port status, ambient temperature
Dimmer:	rating, control level, output level, recorded load (AF only), current load (AF only)

The control module slides out of the rack just as the dimmer modules do, so it can be quickly replaced if it goes down. According to the ETC User Manual, the rack does not need to be powered down; however, care must be taken, because the CEM contains exposed electrical components. Two holes in the bottom panel of the CEM expose live power until the CEM is removed from the rack. The correct way to remove the CEM is to slide the retractable handle out of the front (center bottom edge) and use only the handle to pull the module out. Looking at the circuitry of the CEM module, you will see a small fuse at the back of the module. This should be tested if the module fails. There is also a small switch at the front to the circuit board labeled TEST and NORMAL. Be sure this switch set to NORMAL. TEST puts all the dimmers to full.

Proper ventilation and cooling are essential to all dimmer racks. Cooling air is drawn into the dimmer rack through the dimmer modules. The doors of the touring rack contain an electrostatic filter to keep particulates out of the cooling air. They should be kept closed when the racks are not being worked on. If they are dirty, you can clean them with a vacuum or compressed air hose (blow the dust off *away* from the dimmers not *into* them). A fan exhausts the air through a vent in the bottom of the rack. It is important that this remain clear. Don't let the best boy's *Wall Street Journal* or anything else get underneath the rack and block the air exhaust port. Note that when you are combining Sensor Racks with other kinds of racks in close proximity, you need to be aware of the ventilation patterns of the different racks and avoid feeding exhaust heat from one rack right into a neighboring one.

On the right side of many Sensor touring racks, you'll find a patch panel. This allows the user to customize the patch between the dimmer and the circuit. This feature is very handy for troubleshooting. If you have a bad cable, you can quickly repatch the circuit to a spare cable (You did run some spare cables, didn't you?). Or, conversely, if a dimmer fails, you can repatch the circuit to a working dimmer without having to get into the mass of cables coming out of the back of the rack. The patch panel also has "hot pockets" that allow you to bypass the dimmer and run hard power right to the circuit (convenient for testing). The Patch Panel consists of a panel of numbered patch sockets, one for each dimmer, and a set of cables for each Socapex outlet on the back of the rack. The cables are labeled with the letter associated with the Soco outlet, and the circuits are numbered 1-6, so you have A1-A6, B1-B6, C1-C6, and so on.

The back of the touring rack houses all the input and output connections and also the main circuit breaker. At the top of the rack are the DMX512 IN and THRU data connectors, and Ethernet signal inputs. Sensor touring racks configured with Socapex multipin connectors provide two Socapex connectors for each circuit. The connectors you use have to be patched in the patch panel. You will often only be using every other soco output from the rack. Because the outputs are packed close to one another, it is convenient to offset the rows of connectors. This provides space to get your hands around the connectors. A soco rack also provides 20 A Stage Pin connectors (that are hard-wired and cannot be patched). These are sometimes helpful for troubleshooting. Racks also provide hot pockets on the back and Edison courtesy outlets.

The power inputs are Cam-Lok. Test points are provided above each of the power input connectors. Each of the phase inputs has an indicator light to show whether voltage is present. The test points and indicator lights are protected with 2 AG fuses located next to them.

CHAPTER

14 Working with electrical power

In this chapter, we look at electrical phenomena that affect the way we have to size our distribution cables—namely, line loss and electronic nonlinear loads. We will also discuss ways in which we measure and test electrical circuits, and deepen our understanding of the hazard of electrical shocks.

Let's begin with an overview of the factors that affect the size (or number) of conductors we use in our feeder cables, including phase conductors, neutral conductors, grounding wires, and system grounding conductors. Following this overview, we will look in greater detail at the specifics of voltage drop calculations, and the nature of nonlinear loads.

SIZING DISTRIBUTION CONDUCTORS

As you know, 4/0 is generally the largest cable size that we use, so if a larger cable is required, we increase the number of 4/0 conductors. This is called *paralleling* the cable. When paralleling cables, the cables must all match in length, cable size, and temperature rating. You may sometimes hear cable runs referred to by the terms once used for DC cable runs; when the number of conductors is doubled it is known as a half-million run; tripled = a 750 run, or quadrupled = a million run.[1] Today, an AC cable run is typically referenced simply by the number of total conductors in the run: a three-phase run is a five-piece run, a doubled three-phase run is a nine-piece run (the ground need not be doubled). Determining the gauge and number of conductors needed for a given run depends on a number of factors, which we will summarize in the following sections.

Sizing phase conductors

The sizing of feeder cable boils down to the management of energy in two ways: the control of heat for safety, and the preservation of voltage to allow proper functioning of the equipment. The electrical code prescribes practices that prevent the temperature of the electrical components from exceeding their rated maximum. As described in Chapter 12, the cable must be sized to provide sufficient capacity to carry the full load of the overcurrent device protecting that circuit upstream, allowing for existing conditions. Existing conditions include: the temperature rating of the over

[1]The term *million run* comes from the days when the main feeder cables were larger than 4/0 (believe it or not!) and rated in circular mils. The cable size was 250,000 circular mils. Therefore, one run (250,000 cm) was referred to as a *quarter million run*, two paralleled cables was called a *half million run*, and so on. 4/0 cable has a cross-sectional area of only 211,600 cm, but we still refer to a four-conductor run as a million run—which is easier to say than a "846,400 run," I suppose.

Set Lighting Technician's Handbook, 4e. DOI: 10.1016/B978-0-240-81075-1.00014-3

current device, the length of time, the temperature conditions, and the amount of ventilation. If after derating the cable for these conditions the cable no longer provides sufficient capacity, then a larger cable gauge must be used, or the load must be shared between paralleled feeders.

The minimum cable size that provides sufficient capacity will very often still not be sufficient to prevent a reduction of voltage at the load caused by the resistance of a long length of cable. For a cable that is running near its maximum capacity, any run longer than 150 ft will likely have unacceptable voltage drop. If the voltage at the load is too low, the lights will not function properly. The conductor size must be increased in order to lessen the effect of line loss.

It is easy to calculate the conductor size necessary to avoid unacceptable line loss. We will go over these calculations, and get into a more detailed discussion of line loss shortly.

Sizing neutral conductors

The sizing of the neutral conductor for AC runs is largely dependent on the kind of load being powered. The effects of reactive loads and nonlinear loads will be discussed in detail later in the chapter. As far as cable size is concerned, we can summarize the effect of these loads as follows:

- When loads are purely resistive, the size of the neutral conductor can be the same as that of the phase wires.
- When powering any kind of reactive load (magnetic ballasts, non-PFC electronic ballasts, large numbers of non-PFC fluorescent or LED fixtures), the code requires that the neutral be sized at 130% of the ampacity of the phase conductors. (In practice, if one 4/0 conductor is used per phase, we would simply double the conductors for the neutral. If two 4/0 conductors are used per phase, we could use *three* 4/0 conductors on the neutral, which is 150% of the ampacity of the phase conductors.)
- If phase control dimmers are used, it is best to simply double the neutral conductor of the feeder cables. (For example, if two 4/0 conductors are used per phase, then *four* 4/0 conductors are required for the neutral.)

Sizing equipment grounding conductors

The size of the ground conductor (equipment ground) on the feeder cable is based on the rating of the overcurrent protection (not the wire gage or number of parallel conductors used for the phases wires) and is reprinted from the National Electrical Code (NEC) in Table D.3 of this book. For service with circuit protection up to 1600 A per phase, a single piece of 4/0 is sufficient for the equipment grounding conductor.

Sizing grounding electrode and bonding conductors

The grounding electrode grounds the power source to ground. Ground may be provided by a building service ground, a driven copper rod, or other suitable ground as approved by the AHJ.[2] The size of the conductor that you run from the generator or transformer to the grounding electrode is typically

[2]Depending on where the work is taking place the Authority Having Jurisdiction (AHJ) may be the local electrical inspector, the fire marshal (also known as a Film Safety Officer), or the studio's safety department. The AHJ is the ultimate authority for what practices will be allowed on set and has the authority to stop production if the production does not resolve a safety issue. The AHJ will enforce codes and guidelines that have been adopted locally. The AHJ also has the authority to relax certain rules when there is no other way to manage a situation, and the work can be accomplished safely.

#2 AWG, and would never need to be larger than a single piece of 2/0. It is sized in proportion to the largest service-entrance conductor. For our purposes, if the phase conductors of the service (the generator or transformer) fall between 3/0 and 350 kcmil, a #2 AWG copper conductor can be used for the grounding electrode conductor (NEC Table 250.66).

When multiple power sources are used in proximity to one another, or within the same building, the grounds must be bonded. This is done to eliminate any voltage potential between the ground of one power source and the ground of another. If they are not bonded, it is quite possible to get a shock from a piece of lighting equipment by simultaneously touching building metal such as a metal railing. The size of the bonding wire follows the same rules as the grounding electrode conductor. When attaching the grounding electrode conductor to a building ground, the connection must be made at the main service entrance to the grounding electrode. A standard grounding electrode clamp can be used.

LINE LOSS

Line loss is the erosion of voltage over a long distance caused by the resistance of the feeder cables. The severity of line loss increases with the amount of current carried by a particular conductor, but generally line loss starts to become apparent in feeder cables longer than 100 ft. As a rule of thumb, electricians assume that most feeder cable loses about 4 V per 100 ft. when running at 80% capacity. So you can anticipate a significant line loss any time there is a fairly long run of cable and the cable is loaded near its maximum ampacity rating.

In this section, we discuss the variables that affect line loss. We look at the effects of voltage drop on tungsten lamps, HMI ballasts, and electronic power supplies, and define the concept of "allowable voltage drop." We will discuss the tools that we have to mitigate line loss. We will learn the electrical equations that we can use to make various calculations necessary to avoid unacceptable amounts of line loss. Based on these calculations, we will generate some simple rules of thumb that you can use to determine how to overcome line loss.

Causes of line loss

The three major variables that affect the amount of line loss are length, wire thickness, and amperage load. Remember these three principles:

1. The resistance of a conductor increases directly with its length. The longer the run, the greater the line loss.
2. The resistance of a conductor decreases in proportion to its cross-sectional area. The larger the conductor, the less the line loss.
3. Voltage drop varies directly with the load. The larger the amperage load, the larger the line loss.

Figure 14.1 the shows effect on line loss of increasing the number of parallel conductors. You might think that doubling the cable also allows you to pull more amperage; however, increasing the amperage increases the line loss. The doubled cable gives you a longer run without problems from line loss, but you cannot then add amperage without the problem of line loss returning.

Resistance, heat, and line loss also occur when a connection is weak or loose, when a cable is frayed, when a connector is only partially inserted, or when a connector or conductor is loaded

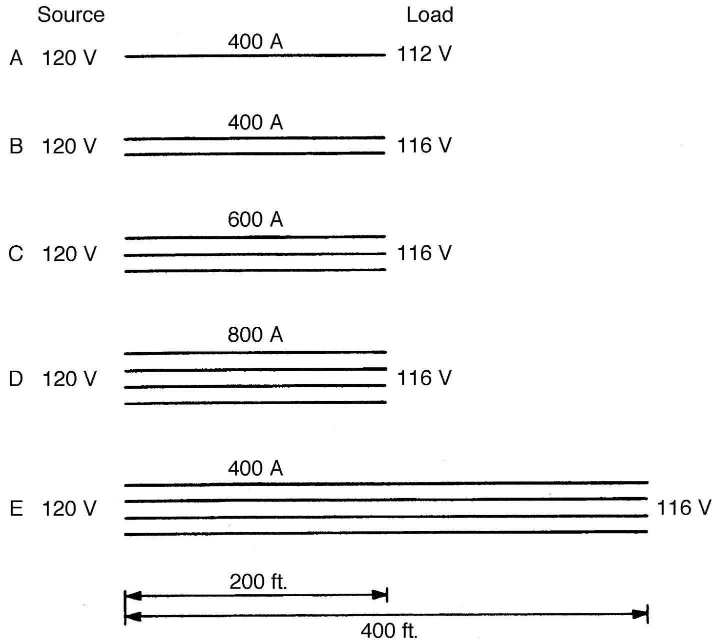


FIGURE 14.1

Voltage drop versus length versus cable size.

beyond its capacity. Stacking cables closely together or within one multiconductor cable (Socapex) or making severe bends in the cable creates a hot spot in the cable and connector. Heat increases resistance, and therefore line loss, and heat also further degrades the insulation.

Circular coils in a single-conductor, current-carrying cable-create impedance, resulting in line loss and increased heating. Good set practices, such as checking for good contact between connectors, locking connectors tightly, taping connectors where necessary, avoiding circular coils, and replacing overheating parts, help rid you of the annoyance of inexplicable line loss and melted connectors.

Allowable voltage drop

Allowable voltage drop is the amount of voltage drop that still allows acceptable performance from the equipment, and does not cause harm to the equipment. The NEC does not regulate allowable voltage drop. In a fine-print note in Section 215.2(A)(3), the code reads:

> *FPN No. 2: Conductors for feeders as defined in Article 100, sized to prevent a voltage drop exceeding 3 percent at the farthest outlet of power, heating, and lighting loads, or combinations of such loads, and where the maximum total voltage drop on both feeders and branch circuits to the farthest outlet does not exceed 5 percent, will provide reasonable efficiency of operation.*

Fine-print notes (as defined in section 90.5(C)) are informational only and are not enforceable as requirements of the code. This note is saying that if a voltage drop in the feeders does not exceed 3%, and does not exceed 5% total (both feeders and branch circuits), the voltage will

Table 14.1 Acceptable voltage drop as percentage of the rated voltage of the load.

Voltage of load	3% (Feeders)	5% (Overall)
120V	3.6V	6V
208V	6.24V	10.4V
240V	7.2V	12V
480V	14.4V	24V

provide "reasonable efficiency of operation." Table 14.1 shows how these percentages translate into volts.

You can see that a 120 V circuit with a 5% total line loss loses 6 V. It will be left with 114 V powering the load. This fine-print note provides very safe guidelines that are commonly used as a reference point. However, the code leaves it to our discretion to provide for our lighting equipment. So the question becomes: what are the tolerances for acceptable performance from our equipment?

The effect of line loss on tungsten lights is dramatic. Light output falls off geometrically as the voltage decreases. The dramatic loss of output was shown in Chapter 12 in the discussion of Ohm's law. We showed how a 2k lamp operating at 90% of rated voltage (108 V) produces about 68% of its normal light output. As the light intensity decreases, so does the Kelvin color temperature of the emitted light.

Loss of voltage also translates into a loss of power. If R is the resistance of a conductor, the equation $W = I^2R$ shows that the power loss in a given cable increases as the square of the amperage. If you double the ampere load on the cable, the voltage drop also doubles, but the power loss increases fourfold. When a system has a large voltage drop, the performance of the generator (its maximum effective load) is reduced.

Electronic ballasts and electronic power supplies for fluorescents and LEDs usually have a range of acceptable voltage. The acceptable voltage range for electronic equipment is typically available online if it isn't written right on the power supply. Electronic HMI ballasts typically perform well in a range from 90 to 130 V or 190 to 250 V. Constant-power electronic ballasts will draw more current if the line voltage decreases in order to maintain constant power to the lamp. A 4 kW HMI that operates at 19 A at 240 V, operates at 22 A at 208 V. If the voltage is reduced to 190 V by line loss, it will draw 24 A. This could lead to overloading the connectors on some ballasts. For example, some rental houses fit their 18 kW ballast with 100 A/240 V Stage Pin connectors. This is a marginal practice, because although the amperage at 240 V is round 80 A per phase; at 208 V, this climbs up to 93 A, which is a lot for a 100 A Bates connector. If the voltage drop brings the voltage down to 190 V, that amperage climbs to 102 A, which will cause the connector to overheat. This is why most rental houses fit their large HMIs with Cam-Lok connectors.

Mitigating line loss

It is perfectly permissible to mitigate line loss somewhat by increasing the voltage at the power source. If the power is from a transformer, this can be done using different taps on a transformer. You need a transformer that provides a tap switch. A transformer typically provides plus and minus 5% output in 2.5% increments. On a generator, a 5% adjustment is usually possible by increasing the field strength of the alternator. Any larger adjustment is inadvisable, as it can destabilize the frequency control of the generator, and according to some suppliers it can harm the generator.

When increasing the voltage at the source, keep two things in mind. First, if equipment is being powered at the upstream end of the cable run (such as the producer's trailer at base camp), the upstream equipment will be over voltage (the producer's computer is toast). Second, voltage drop is proportional to amperage load. When the amperage load is reduced significantly, voltage must be turned down at the generator to prevent any remaining lights from being over voltage. If a lot of big lights are suddenly turned off, the voltage jumps up and the remaining load is over voltage (the sound cart is toast). I use these examples for dramatic emphasis. Clearly, neither base camp nor sound should be powered on the same system as lighting.

Increasing the voltage at the source does nothing to solve the problem of voltage drop; it merely leaves you with a workable voltage after the voltage drop occurs. The power source is having to work a great deal harder to power the load plus the parasitic effect of voltage drop. The I^2R losses mentioned in the previous section still occur. This results in a loss of efficiency, greater fuel consumption (in the case of a generator), and reduction of maximum power available from the power source. The only way to truly reduce these effects is to reduce resistance by adding copper. Calculating how to effectively reduce line loss is the topic of the next few sections of this chapter.

Cable size and other line loss calculations

Figure 14.2 shows equations we can use to make various kinds of voltage drop calculations. These equations are for single-phase loads only. Almost all loads we use in lighting are single-phase loads.

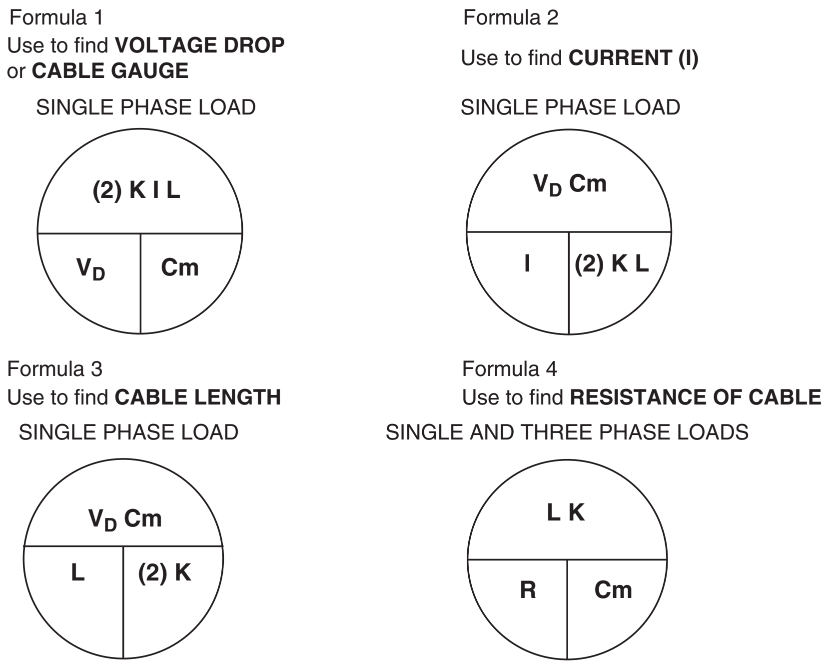


FIGURE 14.2

Voltage drop equations for single phase loads.

Regardless of the voltage (120, 208, or 240 V), unless the lighting equipment requires all three phase wires to operate, it is a single-phase load.

These equations are presented in order to provide a complete understanding of what goes into the calculation. However, the calculations can be significantly simplified with the same result. For a more user-friendly approach, flip ahead a few pages.

We can use the equations in Figure 14.2 to calculate:

- *Thickness* of cable needed to limit the voltage drop to a selected percentage
- *Distance* a particular cable can carry a known amperage
- Exact *voltage drop* for a particular cable at a stated amperage
- Maximum *current* we can send through a given length of cable and not exceed a chosen voltage drop

To use these equations, we first have to define the variables we are using:

L	The *length* of the wire in feet. This is the *one-way distance* from source to load. (Note that in the equations, this number is multiplied by 2 to get the two-way distance the current has to flow to complete the circuit.)
V_D	The voltage drop from source to load.
I	The current carried by the cable.
K	The specific resistance of the material composing a conductor. For copper cable, $K = 10.8$ at 25 °C. Usually K and 2 are combined in the equations: $2K = 21.6$.
Cm	The cross-sectional area of a wire measured in circular mils (cmil). These tend to be pretty big numbers. For example, 4/0 cable has a cross-sectional area of 211,600 cmil. Table 14.2 correlates cmil to wire gauge numbers for common gauges. Table D.2 lists complete cable data.

$$1 \text{ mil} = 1/1000 \text{ in.}$$

$$\text{cmil} = (\text{diameter in mils})^2$$

Finding the voltage drop

The single phase voltage drop equation (Figure 14.2, Formula 1) is used to find the voltage drop when the length, gauge, and current are known:

$$V_D = \frac{(2)KIL}{Cm}$$

$2K$ is 21.6, so

$$V_D = \frac{(21.6)IL}{Cm}$$

Table 14.2 Cross-sectional area and ampacity of cables

AWG (wire gauge)	Cross-sectional area (cmil)	Maximum ampacity (90° cable)[a] (A)
4 × 4/0	846,400	1620
3 × 4/0	634,800	1215
2 × 4/0	423,200	810
4/0	211,600	405
2/0	133,100	300
#2	66,360	190
#4	41,740	140
#6	26,240	105
#12	6530	20

[a]*Noncontinuous loads, single-core cablein in free air, type W and Entertainment Cable.*

Example

For example, what would be the voltage drop if a 1k is plugged into 200 ft. of stingers (#12 AWG)? We know a 1k draws 8.3 A and Table 14.2 tells us that #12 cable has a cross-sectional area of 6530 cmil, so

$$V_D = \frac{(21.6)(8.3\text{ A})(200\text{ ft.})}{6530\text{ cmil}} = 5.5\text{ V}$$

We would be reading about 114.5 V after 200 ft. What would happen if we put on a 2k instead?

$$V_D = \frac{(21.6)(16.67\text{ A})(200\text{ ft.})}{6530\text{ cmil}} = 11\text{ V}$$

We would end up with 109 V after 200 ft. For a tungsten light, this will cause fairly significant decrease in output and color temperature. Depending on the circumstances, this may or may not be acceptable. Let's look at what would happen if we ran a 100A Bates extension instead. 100 A Bates is #2 AWG. Table 14.2 tells us that *Cm* for #2 cable is 66,360 cmil, so

$$V_D = \frac{(21.6)(16.67\text{ A})(200\text{ ft.})}{66{,}360\text{ cmil}} = 1.08\text{ V}$$

A 1-volt drop is quite acceptable.

Finding cable gauge

We can use the same equation (Figure 14.2, Formula 1) to find the thickness of cable necessary to keep within a given V_D for a given length and current:

$$Cm = \frac{2KIL}{V_D}, \quad Cm = \frac{(21.6)IL}{V_D}$$

Example

For example, we are running twelve 10ks (four 10ks per leg) on a 4/0 run 400 ft from the can. If we allow no more than a 5 V drop, how many pieces of 4/0 do we need per leg?

$$Cm = \frac{(21.6)IL}{V_D} = \frac{(21.6)(4)(83.33\text{ A})(400\text{ ft.})}{5\text{ V}} = 575{,}769.6\text{ cmil}$$

Each piece of 4/0 is 211,600 cm. To find the number of pieces we need, we divide 575,769 cmil by 211,600 cmil and round up (or just check Table 14.2):

$$\frac{575{,}769\text{ cmil}}{211{,}600\text{ cmil}} = 2.7\text{ pieces of }4/0\text{ per leg}$$

To go 400 ft., we need three pieces of 4/0 per phase.

Finding the maximum current

To calculate the maximum amount of current you can put through a given length and gauge of cable and remain within a specified voltage drop, use the equation in Figure 14.2, Formula 2:

$$I = \frac{V_D Cm}{(2)KL}, \quad I = \frac{V_D Cm}{(21.6)L}$$

Example

For example, how many amps can we draw per leg on a piece of five-wire banded (#2 AWG) that is 250 ft. long, if we allow no more than 6 V drop?

$$I = \frac{V_D Cm}{(21.6)L}$$

$$I = \frac{(6\text{V})(66{,}360\text{ cmil})}{(21.6)(250\text{ ft.})} = 73.7\text{ A}$$

We can put only 74 A per leg. That's just enough for a 9 kW nine-light Maxi-Brute on each phase.

Finding the maximum length

Finally, we can calculate the maximum length that a given cable may be expected to carry a given amperage and remain within a specified voltage drop using the equation in Figure 14.2, Formula 3:

$$L = \frac{V_D Cm}{(2)KI}, \quad L = \frac{V_D Cm}{(21.6)I}$$

Example

For example, what is the longest length of headfeeder we can have on a 10k and have only a 2.4 V drop? (The power cable for a 10k is #4 cable, rated for a maximum amperage of 140 A).

$$L = \frac{V_D Cm}{(21.6)I}$$

$$L = \frac{(2.4\ \text{V})(41{,}740\ \text{cmil})}{(21.6)(83.3\ \text{A})} = 55.7\ \text{ft.}$$

Using a 25-ft extension and a 25-ft head feeder the branch circuit has reached 2% voltage drop.

The final equation (Figure 14.2, Formula 4) allows you to calculate the actual resistance of a cable or the area of a cable given its resistance in ohms.

You might find the results of these calculations surprising. We routinely load cables to near their maximum ampacity and run them out a couple hundred feet. However, to avoid serious voltage drop, when long lengths of cable are needed, we need to increase the cable size. Instead of running 200 ft. of stingers, use a 100 A Bates. Instead of running a city block with banded, put in a 4/0 run.

Line loss calculations for three-phase loads

To make line loss calculations for a three-phase load (such as a Luminy's Softsun, a three-phase step-down transformer, or a three-phase xenon power supply) you make one substitution in the equation: replace the 2 in the equations with 1.73.

Simple line loss calculations

If you look at the voltage drop equation above you can see that for a given cable, all the variables are fixed except current and length. We can therefore boil the equation down to a very simple rule of thumb. Because we usually work with cable lengths in hundreds of feet, we can state the voltage drop equation very simply as follows:

4/0 cable: 1.02 V per 100 A per 100 ft.
2/0 cable: 1.62 V per 100 A per 100 ft.
#2 AWG banded: 3.25 V per 100 A per 100 ft.

This will give the same result as the equations explained in the previous section. This rule of thumb assumes single-phase loads. (Any load having two current-carrying wires—either 120, 208, or 240 V—is a single-phase load.)

Example 1

If you calculate the load to be 300 A, and the run is 200 ft. using 4/0 cable, the total voltage drop will be:

$$1.02 \times 3 \times 2 = 6.12\ \text{V}$$

This is a really simple calculation, and you'll notice that for 4/0, it could be made even simpler, because the factor 1.02 is so close to 1.0 that it could even be eliminated if you wanted to make a quick, rough calculation in your head. 300 A at 200 ft. is $3 \times 2 = 6$ V.

As explained earlier, you would then divide the total voltage drop by the allowable voltage drop to get the number of 4/0 conductors required. For this example, let's say you wanted to use 3% voltage drop—3.6 V.

$$\frac{6.12}{3.6} = 1.7 \text{ conductors}$$

So you would run two 4/0 conductors per phase.

Example 2

Let's try slightly more complicated numbers. You have a 520-A load on a 650 ft. run of 4/0.

$$1.02 \times 5.2 \times 6.5 = 34.48 \text{ V}$$

$$\frac{34.48}{3.6} = 9.6 \text{ conductors}$$

So you would have to run 10 4/0 conductors per phase to limit voltage drop to 3%. If you decided that your load would run just fine with a 6 V drop, then you could recalculate:

$$\frac{34.48}{6} = 5.7 \text{ conductors}$$

and use just 6 4/0 conductors per phase.

Example 3

Let's try one more using #2 AWG banded cable. Let's say you are powering an 18k at the end of a 250 ft. run. The 18k pulls about 93 A per phase at 208 V.

$$3.25 \times 0.93 \times 2.5 = 7.6 \text{ V}$$

The 18k ballast will be receiving around 200 V ($208 - 7.6 = 200.4$ V), and would be expected to run just fine (electronic ballasts are generally okay down to about 190 V). Note that 7.6 V is just a little more than 3% (6.24 V for a 208 V load).

POWER PROBLEMS FROM ELECTRONIC LOADS

Much of today's lighting technology relies on electronics such as DC rectifiers, tryristors (SCRs), and high-frequency switching power supplies (IGBTs) with large capacitors on the front end. These loads can have undesirable effects on the current waveform, with associated ill effects such as overheating or failing equipment, efficiency losses, circuit breaker trips, excessive current on the neutral wire, interference and instability with generators, noisy or overheating transformers and service equipment, and even loosened electrical connections. In the following sections, we discuss the power factor and current harmonics and look at their effects. Your awareness of these effects will help you to intelligently test for problems and build systems that avoid or mitigate them.

Like a landslide, technology continues moving toward more and more dependence on electronic devices that have such effects. Office buildings full of fluorescent lights and computer equipment experience the same problems, because the power supply of every PC, printer, copy machine, and electronic ballast in the building creates harmonics that build on one another. These problems are already regulated in Europe and will soon reach a point in the United States where technology and regulation are forced to address the situation and provide new tools for dealing with it. Much discussion and research is underway already. In the meantime, here's what to look for. We start with the milder problem of power factor. Power factor, as it applies to HMI power supplies, was introduced in Chapter 8.

Power factor

When we calculate cable loads and generator loads, we use the equation

$$\frac{\text{Watts}}{\text{Volts}} = \text{Amps}$$

However, with some AC equipment, this equation is not true, as *it underestimates the actual current*. When a piece of equipment has inductive properties (magnetic ballasts) or capacitive properties (electronic ballasts and electronic dimmers), the *power factor* must be considered to make proper load calculations.

Inductive reactance

An incandescent light has no inductive or capacitive properties. It merely creates resistance in a circuit. A purely resistive circuit is said to have a power factor of 1.0 (also called a *unity* power factor or 100% power factor) and the equation watts/volts = amps is correct. When an AC load involves coils, such as those in a transformer, motor, or magnetic ballast, it creates resistance *and inductance*. As the current increases and decreases (120 times/second) in a coil carrying AC current, a magnetic field expands outward from the center and then collapses back inward again. As the current increases, the circuit stores energy in the magnetic field; then, as the current decreases, the circuit gets the energy back. The energy drawn and released by the magnetic field does not accomplish any actual work; energy just keeps circulating back and forth between the coil and the power source. When the lines of flux of the magnetic field grow and collapse, they self-induce a voltage in the coil; this is called the *counter-electromotive force* (counter EMF). The counter EMF has the opposite polarity of the applied voltage. As a result, the applied voltage must overcome the induced voltage before current can flow through the circuit. This opposition to the flow of current is called *inductive reactance*.

The effect of reactance is clear when you look at the waveforms of voltage and current (Figure 14.3). The increase and decrease of current normally corresponds with the increase and decrease of voltage, 120 times/s (Figure 14.3A). Inductive reactance causes current to *lag* behind the voltage (Figure 14.3B). The degree to which the two waveforms are put out of phase is expressed by the cosine of the *phase angle* between them. The phase angle depends on the relative amount of resistance and inductance offered by the load. The more they are out of phase, the lower (poorer) the power factor.

Capacitive reactance

Similarly, if the circuit has a capacitive component (electronic ballasts), *capacitive reactance* produces a power factor of less than 100%. Capacitive reactance acts on the waveform in a way opposite

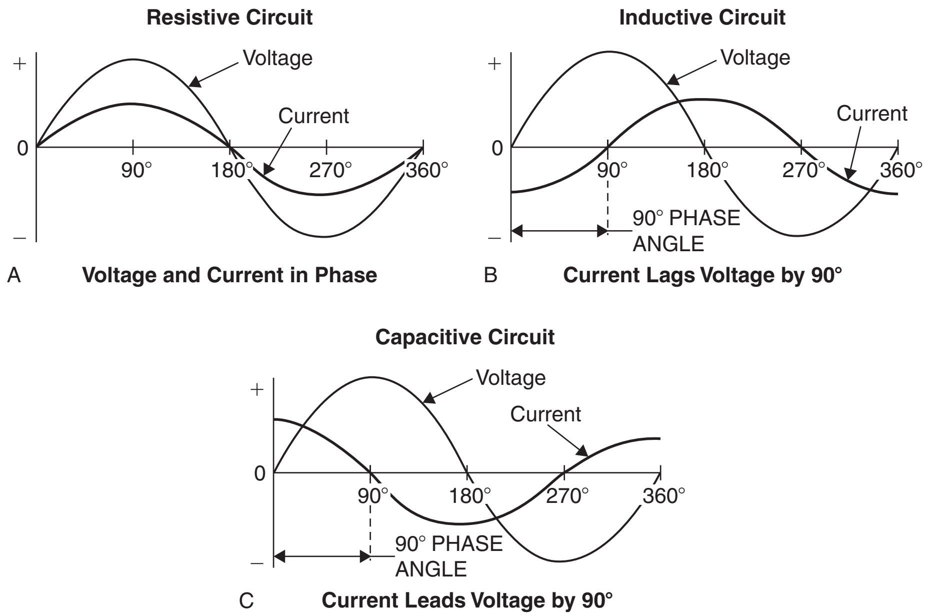


FIGURE 14.3

The effect of (A) resistance, (B) inductance, and (C) capacitance on the voltage/current phase relationship.

to inductive reactance. It causes current to *lead* voltage (Figure 14.3C). As mentioned in Chapter 8, some HMI ballasts have power factor correction circuits, which help restore the efficiency of a ballast. In fact, because a capacitor has the effect on the current waveform opposite to an inductor, capacitors are used to help correct the effects of inductive reactance. Conversely, inductors help counter capacitive reactance, which aids in returning a waveform that is out of phase to normal.

What is the power factor?

The power factor (*pf*) is the ratio of *true power* to *apparent power*:

$$\frac{\text{true power (W)}}{\text{apparent power (VA)}} = \text{power factor}$$

If you were to measure the current and the voltage, then multiply the two together, you get what's called the *apparent power* (expressed in volt-amperes).[3] This is the amount of power traveling back and forth in the cables.

For single-phase loads, volt-amperes = volts × amps:

$$E_{\mathrm{RMS}} \times I_{\mathrm{RMS}} = VA \ \text{(apparent power in volt}-\text{amperes)}$$

[3]Such a measurement would have to be made with a true RMS meter, not a common multimeter.

True power is the actual amount of energy being converted into real work by the load. You can read true power using a *wattmeter* (see the section on "Measuring Electricity" later in this chapter).

$$E_{\mathrm{RMS}} \times I_{\mathrm{RMS}} \times pf = \text{true power (W)}$$

As one electrician put it, if apparent power is a glass of beer, power factor is the foam that prevents you from filling it up all the way. The size of the feeder cables and the rating of the power source must be sufficient to supply the *apparent power* (beer plus foam), even though only the beer (true power) counts as far as how much actual drinking is possible. Load calculations must therefore include the power factor.

Power factor calculations

The power factor of a ballast or motor is sometimes, but not always, written on the equipment. To calculate the actual amperage needed to power equipment when the power factor is known, use the following equation:

$$\frac{\text{true power}}{E \times pf} = I$$

where true power is the rated wattage of the equipment, E is the voltage, pf is the power factor, and I is the current.

To illustrate, suppose that we are powering four 6k HMIs. If we made the mistake of discounting the power factor, we would incorrectly calculate the amperage as follows:

$$\frac{4 \times 6000\ \text{W}}{120\ \text{V}} = 200\ \text{A}$$

If the units have a power factor of 0.70, the actual amperage required is

$$\frac{4 \times 6000\ \text{W}}{120\ \text{V} \times 0.70} = 286\ \text{A}$$

From this, we see the importance of taking the power factor into account. The amperage is significantly higher than thought—86 A higher.

Harmonic currents and effects on the neutral wire

A nonlinear load is one in which the current does not track with the applied voltage. There is an ever increasing number of electronically powered devices in which high-speed switching does not turn the device on until the voltage reaches a predetermined point in the sine wave. Then the device turns on until voltage reaches another predetermined point. This results in the waveform of the current not following the waveform of the applied voltage. The resulting current has an irregular, even erratic-looking waveform. However, it has been determined that the wave form is in fact the summation of the fundamental frequency (60 Hz) with varying amounts of harmonic frequencies, especially third-order (180 Hz) and fifth-order (300 Hz) harmonics (Figure 14.4). Like in music, harmonics are multiples of the fundamental frequency. In music, harmonics are what make chords sound so rich. In electricity, harmonics are just a damn nuisance. Similar to conventional power factor deficiencies, the harmonic currents create heat in the cables and circuits and power source (transformer coils or generator windings) without doing any work.

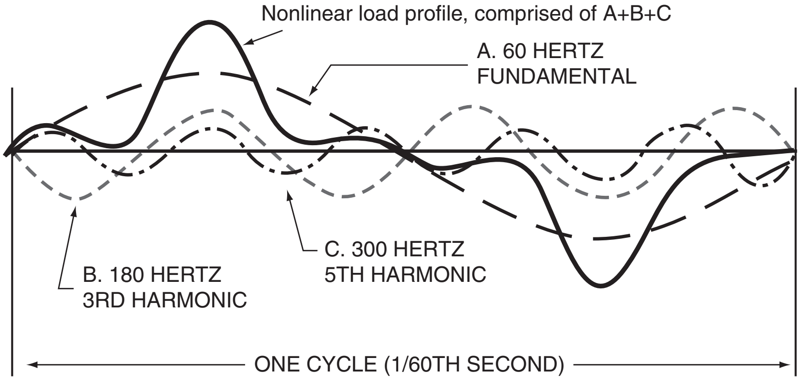


FIGURE 14.4

Nonlinear loads produce distortions on the current waveform that are the summation of first-, third-, and fifth-order (and higher) harmonics.

When an inductive or capacitive load causes current and voltage to be out of phase, or when harmonics are present, the phase currents no longer cancel when they return on the neutral. When using magnetic ballasts, it is normal to have as much as 20-25% of the total amperage return on the neutral when the phase legs are evenly loaded. For this reason, when using many magnetic ballasts, it is wise to provide a neutral that is at least as large as the phase wires.

Electronic dimmers and electronic ballasts not corrected for power factor use electronics that create harmonic currents that can stack on top of one another, creating very high currents returning to the power source on the neutral wire. Manufacturers of phase control dimmers typically recommend that the neutral be capable of carrying 1.4 times the phase current. The NEC requires for nonlinear loads the neutral conductor be able to carry at least 1.3 times the phase current. This is why we always simply double the neutral cable when powering these loads. By the same token, you risk overloading the neutral wiring of the transformer or generator if its wiring is not sized to handle return current, especially with 208Y/120 circuits. When return current could be a problem, it is wise to oversize (derate) the generator or transformer or use an appropriate K-rated transformer (see Chapter 16).

MEASURING ELECTRICITY

There is an important distinction between voltage testing branch circuits at the load-end of the distribution system, and voltage testing of the power source (especially inside an electrical panel in proximity to live exposed conductors). In both cases, the person doing the metering must be properly qualified, but their qualifications in one location are quite different from those in the other location. In addition, the metering equipment itself is quite different. It is not within the jurisdiction and training of lighting technicians to perform any task that requires opening up electrical panels and metering exposed live conductors.

The kind of metering a lighting technician is routinely expected to perform tasks like checking the voltage at a distribution box at the end of the feeder run to:

- Check whether a circuit is live
- Check for proper polarity and ground
- Check whether the system voltage is as expected (to be sure feeders are connected properly)
- Check for voltage drop

Meter categories

A variety of testers and metering equipment are commonly put to use by set electricians, and rigging crews. These range from inexpensive voltage testers to full-featured digital multimeters that incorporate line frequency, and amperage in addition to voltage, resistance, and continuity. These features come in handy when troubleshooting or ringing out a new rig.

When measuring voltage of a distribution box or Edison outlet, an inexpensive (UL-listed) voltage tester is quite sufficient; however, this kind of meter provides none of the protections that are required for metering upstream service equipment or any kind of exposed live parts. The location in which an electrical meter is used determines the rating required for that measuring instrument according to the IEC 1010 standard.

Cat I	Electronics within an appliance or device
Cat II	Branch circuit receptacles and commercial loads
Cat III	Permanently installed loads like motors, AC distribution panels or commercial lighting.
Cat IV	Service entrance, main panel, and service meter

The closer you are to the power source, the higher the category rating required for the meter. The higher the category, the less impedance exists between you and the power source, and the higher the energy available. A meter rated for Cat IV work has thicker insulation on the test probes, bigger internal distances between electrical points, a fuse to protect the meter and the user, and a fuse to help protect against high-energy transient voltages. An electrician working in a Cat IV location is required to wear personal protection equipment, including a face mask, electrical gloves, a welder's jacket, and fire retardant clothing. The point is that taking readings from a service panel is not a matter of guts; it is a matter of being properly equipped and trained. It is quite possible for an improperly used meter to short the circuit, arc, or blow up in the user's hand. Meters designed before 1997 will not have the necessary protections required by the IEC 1010 standard. For our work, a Cat II-rated meter, or higher, should be used to do voltage testing on branch circuits. Cat III should be used upstream closer to the power source. Be sure you have a meter that's correctly category-rated for the work you are doing. For voltage testing, use a meter with shrouded connectors and finger guards, and recessed input jacks.

Voltage meters

Lighting technicians usually carry some kind of voltage meter with them at all times. Meters and testers come in many shapes and sizes. A simple voltage tester (Figure 14.5H), when connected across a circuit, uses three LED indicator lights to show whether a circuit is 120, 208, or 240 V.

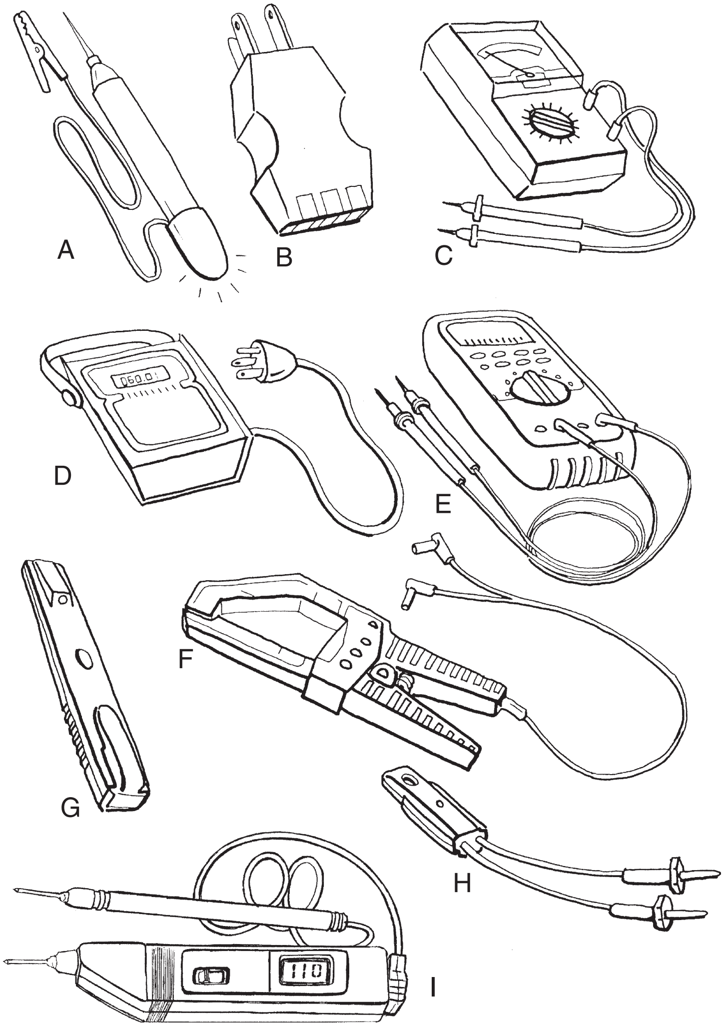


FIGURE 14.5

Meters for measuring electricity: (A) continuity tester, (B) circuit tester, (C) voltmeter, (D) line frequency tester, (E) digital multimeter, (F) amp probe attachment for a multimeter, (G) voltage sensor, and (H) voltage tester. A digital multimeter (I) can read continuity, voltage AC and DC, and resistance.

Most electricians invest in a small digital multimeter (Figure 14.5I) that measures AC and DC voltage, detects continuity, and measures resistance. These are usually "average-responding" or "RMS-calibrated" meters. This type of meter assumes the waveform being measured is close to a pure sine wave and works fine for most lighting loads: however, they read 30-70% low when harmonic distortion is present. A true RMS voltage meter and amperage meter are necessary to make accurate readings when using nonlinear loads such as electronic dimmers and ballasts.

A true RMS meter's analytical circuits can measure and calculate the actual heat caused by a current regardless of the wave shape.

Here are some general precautions when you are setting up to take readings:

- Be sure that your hands, shoes, and work areas are dry.
- Set the meter on a stable surface or hook it over a stable vertical surface. If one of the probes is attached to the meter, place your body so you will not have to strain, twist, or get off balance to see the readout.
- Avoid taking readings in extremely humid or damp conditions or where there is dust or sawdust in the air. These conditions increase the risk of an arc.
- Be sure the meter leads are in good condition with no exposed wire and that they are connected to the proper meter jack.
- Select the type of service being read (AC or DC) and select the voltage range (if applicable). If metering unknown values start with the highest range, then change to a more accurate setting once you know the correct range.
- Many metering accidents are caused by having the meter in amperage reading mode, or resistance or continuity mode when reading a live circuit.
- Voltage readings require that you touch the two meter probes to two live terminals in the circuit. When probing terminals, be extremely careful as you position the probes not to put your fingers on or close to the probes or live parts.
- Touch the probes to the neutral terminal first, and phase terminal second. Disconnect from the phase terminal first, and the neutral second.

The nicer digital multimeters have two displays that simultaneously display voltage. A large digital readout gives you the number of volts. This display is updated four times a second. A smaller bar graph under the number gives an almost instantaneous readout of voltage (30 times/second). The bar graph is helpful in spotting momentary voltage drops.

Circuit testers

A circuit tester (Figure 14.5B) is used to test Edison outlets. It tells you whether (1) the circuit is hot, (2) the polarity is correct, and (3) the grounding wire is present. If you work regularly with 20 A Bates connectors (more common in theatrical applications), consider a Gam Chek Jr., which is a Bates circuit tester that hangs on a lanyard around your neck. A similar device is available for Socapex cable.

A voltage sensor (Figure 14.5G) is a handy device that senses the magnetic field of electricity by simply putting the sensor close to an insulated cable. Although it gives no quantitative reading of amperage, the sensor is useful for checking whether a wire is live. Put the sensor near the wire, and press the button. If it beeps or lights up, then the wire *may be* live. I say *may be* because these testers are prone to give false positive readings. One can occasionally get a positive reading from a wire that is connected to nothing at both ends. You can get tools such as a screwdriver, lineman's pliers, or crimper/stripper tool with voltage sensor built-in (Circuit Alert is one model).

Measuring frequency (hertz rate)

A frequency meter is used to measure the frequency of an AC circuit in cycles per second (Hz). Knowing that the generator is providing a frequency of exactly 60 Hz is necessary when powering HMIs from magnetic ballasts. There are several types of frequency meters, and this is a function

available on the more sophisticated digital multimeters. The most popular frequency meters simply plug into an Edison outlet (Figure 14.5D). In addition, some clamp-on ammeters have a hertz-reading function.

Another type of frequency meter, the Cinecheck meter, optically reads the frequency of the flicker from an HMI fixture (running on a magnetic ballast only). Simply hold the meter up to the light and read the frequency.

Measuring amperage

An "amp probe," or clamp-on ammeter (Figure 14.5F), is used to determine the amperage traveling through a single conductor. Amp probes are generally AC-only; however, some more sophisticated meters can measure DC amperage as well. The amp probe has two curved fingers that close around an insulated single conductor cable. The probe measures the strength of the magnetic field created around the cable by the current running through it. The strength of the field is proportional to the amperage running through the wire. The amp probe gives a reading in amperes.

When reading nonlinear loads (electronic dimmers and ballasts), use an AC-only true RMS ammeter. The AC/DC types do not give accurate readings when harmonics are present.

Be sure to read the instructions for the meter you are using. Meters sometimes have an odd way of scaling. For example, when using the clamp-on pickup with some multimeters, the meter reads amps on a millivolt scale. One millivolt equals one amp. Do not use an amp clamp in a tight enclosure where there are exposed conductors.

Testing continuity and testing for shorts

Unlike all the other testing equipment discussed in this section, a continuity tester (Figure 14.5A and I) is used only when power is *not* connected to the circuit. The tester is used to check for a break in the line. If the line is continuous, the tester will beep or light up.

A continuity tester is handy to check whether a bulb or fuse has blown or whether there is a broken wire somewhere in a cable. If the filament of the bulb is intact, the tester will show continuity across the terminals of the bulb.

If you are checking continuity on a piece of cable, it is often easier to do it from one end, rather than having to touch one probe to each end. If the cable has bare wire ends, you can do this by simply twisting the wires together on one end, and then reading continuity (up and back) from the other end (Figure 14.6A). If the cable has connectors on the ends, make a testing aid—a male connector with a jumper wire connecting all the contacts. Now, it is a simple process to plug the connector onto the female end of the cable and read continuity between each of the male contacts at the other end. (*Note*: You might want to label your device with a warning like "Testing Aid. WARNING DEAD SHORT.")

If you suspect a short in a piece of cable or equipment, you can use a continuity tester to check for continuity between wires (Figure 14.6B). If you find continuity, there is a short. Check each combination of wires (neutral and phase, neutral and ground, phase and ground). You can check a whole cable run this way. If you find a short, just be sure that you haven't overlooked a path for continuity before you jump to conclusions (remove the bulb before testing for shorts on a light fixture).

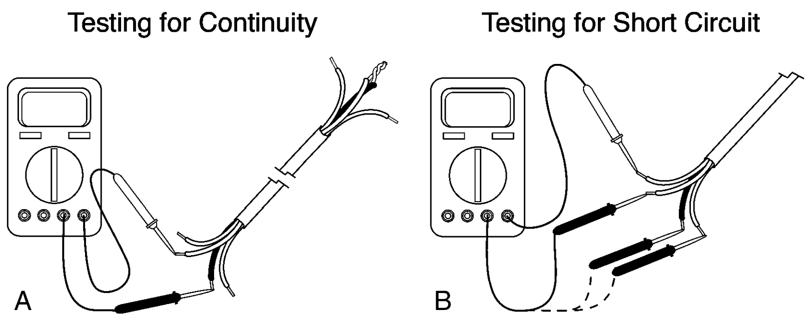


FIGURE 14.6

An easy way to shop-test continuity in a cable is to twist the wires together at one end and read continuity at the other end, as shown (A). If you get a beep, both wires are good. (Use a jumper wire or make a testing plug to short out the conductors when the cable has connectors attached.) You can also use the continuity meter to check for shorts between wires (B) by touching a meter probe to one wire, then checking each of the other wires. If you get a beep, there is a short between those two wires.

Wattmeter or power meter

A wattmeter or power meter has a clamp-on device like an ammeter, and probes like a voltmeter. It reads true power (W) in a circuit. This meter can account for the phase difference between current and voltage when there is inductive or capacitive reactance in the circuit. Some power meters require you to turn off power to the circuit when connecting and disconnecting the meter, then turn on power to take readings. A wattmeter also reads amperage and voltage separately, which together give you the apparent power (see section on "Power Factor"). You can determine the efficiency of power use by dividing true power by apparent power (which gives you the power factor), and multiply by 100 to get *pf* as a percentage.

ELECTRICAL SHOCKS AND MUSCLE FREEZE

Some important rules to live by when working with electricity:

- Whenever possible, plan so that you can work with de-energized circuits.
- Follow lock-out/tag-out procedures to prevent someone from inadvertently energizing a circuit while it is being worked on downstream.
- Use well maintained, properly rated tools and test equipment.
- Use appropriate personal protection equipment.
- Don't work alone.

In the event that an electrician comes into contact with a live wire and completes a circuit, the biggest danger is that his muscles will contract and freeze, and he will not be able to pull away from it. If this happens, the most important thing is to *turn off the electricity* and get him away from the current as quickly as possible. The severity of an electrical injury and the likelihood of cardiac arrest and death is directly proportional to the length of time a person is shocked. *Do not touch someone who is being electrocuted.* Unless you can move faster than 186,000 miles/second (the speed of

light), you will become part of the circuit. *Turn off the power first*. If you cannot turn off the power quickly, pushing the victim with a wooden plank or an apple box is a safe way to disengage him from the circuit. A running, jumping body block can work as long as you are in the air when you hit the victim and do not complete a circuit to ground. This kind of stunt may result in injury to yourself and the victim from hitting the ground or equipment, but it will perhaps save a life. Often the injuries sustained from a shock incident are the result of the fall afterward.

Once the victim is away from the circuit, check for pulse and breathing. Begin CPR immediately if there is no pulse. Call for professional medical assistance. It is very important that a person who has received a shock go to the hospital, have his or her blood checked, and be looked over by a doctor. There may be no exterior signs of injury after a shock, yet even without any outward signs, electrocution can cause serious injury to internal muscles and organs. It has happened that a person walked away from a shock accident only to have a heart attack two days later when the injured heart muscle seized up. A doctor can check the electrolytes in the patient's blood and prescribe muscle relaxants and other therapy if he or she sees a potential risk. The electrician who has been shocked may not even want to go to the hospital. He or she may feel embarrassed and want to play down the accident. He or she may feel fine and not want to be taken out of work. Keep in mind that this person is probably not thinking very straight. Always report any kind of injury. It could seem like nothing at the time, yet turn out to be something serious. If you report it to the medic, you have started a paper trail, which will be necessary later to establish that the injury was work-related.

In addition to the duration of contact, the severity of damage from a shock is determined by the number of vital organs traversed, especially the heart. The most lethal path electricity can take is into one arm and out of the other. As electricity travels across the chest and through the heart and lungs, it can very easily cause ventricular fibrillation or stop the heart entirely. This is the reason that electricians put one hand in their back pocket or behind their back when dealing with live parts.

It is a common misconception that voltage is what kills a shock victim. In truth, high voltage can be dangerous because it has a tendency to arc, but the amperage is what damages the muscles and heart.

The amperage of a shock is a combination of the current in the circuit and the resistance present (Table 14.3). The resistance of dry skin, for example, is about 100,000 Ω. This resistance is enough for brief contact with a 100 V circuit to allow about 1 mA, or 0.001 A, to flow through the body, which is enough to bite but not enough to cause damage (Table 14.4). In contrast, the resistance of wet skin is about 1000 Ω, which allows about 100 mA to flow through the body. This is enough to cause ventricular fibrillation, impede breathing, and cause unconsciousness and possibly death.

Table 14.3 Effect of resistance on amperage of shock

Condition	Resistance (Ω)	Milliamps (mA)
Dry skin at 100 V	100,000	1
Wet skin at 100 V	1000	100
Through an open cut at 100 V	500	200
Dry skin at 10,000 V	100,000	100

Table 14.4 Effect of ampacity on shock victims

Current	Effect on body
1 mA or less	No sensation (not felt)
More than 5 mA	Painful shock
More than 10 mA	Muscle contractions, could “freeze” some people to the electrical circuit
More than 15 mA	Muscle contractions, can cause most people to become frozen to the electrical circuit
More than 30 mA	Breathing difficult, could cause unconsciousness
50-100 mA	Ventricular fibrillation of the heart possible
100-200 mA	Ventricular fibrillation of the heart certain. Death is possible
Over 200 mA	Severe burns and muscular contractions; the heart is more apt to stop beating than to fibrillate. Death is likely
1 A or more	Permanent damage to body tissues, cardiac arrest, severe burns, and probable death

Every electrician must have a healthy respect for electricity if he or she aims to have a long and successful career. People are killed every year by accidental electrocution. Pressure, stress, long hours, and physical exhaustion can cloud good judgment and clear thinking. Be aware of your physical and mental state. As a professional, your judgment of a situation has weight; don’t discount it. No matter how frantic things get, when it comes to dealing with electricity, remember to slow down, think about what you are doing, and don’t let anyone distract you. No situation in filmmaking is worth the risk to your life and health.

CHAPTER

Electrical rigging

15

The job of the rigging crew is to install all the cable and distribution equipment so that the large amounts of electricity needed for production can flow safely from the power source to the lights all over the sound stage or practical location. It is the responsibility of the rigging gaffer to design and estimate the rig, oversee its installation, have it tested, and troubleshoot any problems before the production crew arrives to begin photography. A well-rigged set is orderly, well labeled, and well thought out; gives electricians easy access to power; and does not get underfoot. The rigging gaffer can dedicate the time and forethought to set things up in a way that avoids any extra work or delays for the lighting technicians during production, and eliminates potential hazards. To a rigging gaffer, neatness, straight parallel lines of cable, clear consistent labeling—these are things of beauty and satisfaction.

In this chapter, we look at the role of the rigging gaffer and the techniques of good rigging. We will discuss rigging strategy, rig testing, and the knots a rigger needs to know. We will also look at some of the record-keeping tools used by best boys and rigging gaffers.

THE ROLE OF THE RIGGING GAFFER

In Chapter 13, we discussed all kinds of distribution equipment. One of the first things the rigging gaffer has to figure out is which and how much of all of this stuff he or she needs for the job at hand. Beyond the distribution equipment, the rigging gaffer has to think through the logistics, special equipment, transportation, labor, and time requirements, and get approval from the production manager. The rigging gaffer and the production department coordinate the work of the rigging crew with that of many other departments.

The rigging gaffer's responsibilities:

- Scout the locations, making notes of the lighting, power and special equipment needs. Measure the distances (usually by counting paces) in order to estimate cable. Google Earth also has a distance measuring function, in case you can't do it on the scout.
- Coordinate with the locations department to gain permission and access for placing generators, cables and lighting equipment as desired by the gaffer and DP (in other people's yards, on rooftops, in public driveways, in the street, and so on).
- Plan the routing of cable (an efficient use of cable combined with routing that keeps cable out from under foot and invisible to camera).
- Plan power to provide sufficient amperage capacity in all lighting positions around the set.

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- Calculate line loss and design the rig to remain within acceptable parameters.
- Plan placement of distribution boxes, outlets boxes, and dimmer circuits for ease of use.
- Plan control of lighting using dimmers and remote switches, via a lighting control network or manually.
- Estimate and request personnel for all the work, including rigging, wiring practical fixtures, and setting up the control network.
- Submit equipment orders for the cable and lights and dimmers for the rigs.
- Submit order for expendable supplies.
- Submit orders for special equipment, including generators, Condors, genie lifts, scissor lifts, hoists ("mule" winches), forklifts, all-terrain vehicles (ATVs), and so forth needed to accomplish the work.
- Coordinate the rigging of lighting positions with the key rigging grip. Specify weight loads for truss, chain motors, and waterfalls. Help coordinate the efforts of the two departments.
- Safety: assure the rigging is free of hazards and neatly squared away. If a hazard cannot be eliminated, post warnings, use barricades, and notify appropriate personnel. Consider any physical hazards that the crew could trip over, get hooked on, bonk their heads on, get poked in the eye with, get burned by, run into in the dark, fall from, be electrocuted by, and so on.
- Test the power system from beginning to end, including the lights.
- Prelight: place, focus, gel, diffuse, rough it in for the shooting crew.
- Label everything and provide a light plot for gaffer and first unit crew, and a dimmer hookup sheet for the dimmer board operator. Electricians unfamiliar with the rig need to be able to quickly orient themselves to the layout.
- Coordinate with other departments—in particular, the production designer, set dressers (installation of practical light fixtures), construction coordinator, locations manager, transportation department, grip department, and of course, the production manager and production staff. This includes providing the locations manager with a schedule of the rigging crew's activities, so the manager can make arrangements for parking, bathrooms, and transportation for the rigging crew. Arrange with transportation to have trucks or other vehicles available when needed.

PLANNING THE RIG

We talked about scouting in Chapter 2. Based on his or her notes from the scout, the rigging gaffer will have a pretty good idea of:

- The major light sources for each set.
- The length of cable runs.
- What cable size will be required (but he or she will make some voltage drop calculations to confirm the estimate).
- What power is available in each of the sound stages, or on location.
- The location of the service ground at each location.
- Location of the dimmer shack and waterfalls.
- A place for electrical staging area and the Gold Room (electrician's office).
- The placement of the trucks and generators.

- The DP may want lights inside buildings across the street or streetlight effects on background buildings. There may be platforms for area lighting, such as Condors or scissor lifts, that will require power, and perhaps a separate generator and cable run.
- Equipment with special power requirements such as Lightning Strikes! (see Chapter 18), SoftSun 480-V lights (see Chapter 18), chain motors, and wet locations (see Chapter 17).

From this, the rigging gaffer has to calculate the cable order and lighting inventory for the rig. It is helpful to start by drawing a plot. The gaffer and DP may have already drawn a basic light plot showing the sets and indicating where lights will be rigged, or the rigging gaffer may do this based on his or her notes. A more detailed discussion of light plots as they are used in the motion picture business is available on the *Set Lighting Technician's Handbook* Web site. It includes an explanation of different types of plots, maps, and cheat sheets commonly needed in our work. It includes an overview of drafting conventions, drafting tools and CAD software used to create light plots (such as Vectorworks Spotlight).

In the process, the rigging gaffer gives attention also to the question of control. Which and how many circuits need to be controlled on dimmers? Which lighting devices will be networked (via DMX or Ethernet) to the control console? From the plot, it is easy to see how many lights will have to run from each branch circuit, and how many dimmer lines are needed. The rigging gaffer adds up the amperage requirement for each branch circuit and adds to it a generous amount of power for lights that will be added by the production crew. On a big stage rig, the rigging gaffer will allocate entire circuits for this purpose so that the rigged lights can be totaled separately.

When using three-phase power, attention also has to be given to the question of how the phase wires will be balanced. The math is not hard, but it can be tedious, and it is easy to miscalculate and have to do it over. A spreadsheet program like Microsoft Excel can make this easier by giving a running total of each column as you type in the loads. This makes it easy to see where to place the loads to balance the phases. Start by listing all the lights from biggest to smallest, as shown in Table 15.1, and then assign each load to phase(s), always adding first to the phase with the lowest total load. A quick way to confirm that you haven't made any mistakes is to compare the total amperage of the lights to the total of all three phase loads added together, as shown at the bottom of Table 15.1 (total load amps 894 = 291 + 312 + 291).

In the process of doing this, the rigging gaffer will determine from which circuit lights can be powered—be it from one or more generators, transformers, or service panels.

Size and number of conductors

Next, the rigging gaffer calculates how much copper will be needed—what size cable for each circuit, how many and what gauge conductors to use for the feeder. The sizing of phase conductors, neutral conductors, equipment grounding conductors, and ground electrode conductors are subject to various provisions of the electrical code, and is affected by the type of load being used. The guidelines and calculations for making these determinations were covered in Chapter 14.

Estimating the required capacity is something of a balancing act. One wants to provide adequate copper to control voltage drop within reasonable tolerances and still provide for lights that may be added later. One also has to make an assessment of *demand factor*—that is, calculating the capacity

Table 15.1 Example of a load-balancing calculation

Service: 400 A 208/120 V					
			Amps per phase		
Unit #	Fixture	Total Load (amps)	*Red*	*Blue*	*Black*
1	18k HMI Fresnel	186	93	93	
2	18k HMI Fresnel	186		93	93
3	18k HMI Fresnel	186	93		93
4	18k HMI Fresnel	186	93	93	
5	6k HMI PAR	66		33	33
6	2.5k PAR	24			24
7	2.5k PAR	24			24
8	1.2k PAR	12			12
9	1.2k PAR	12	12		
10	1.2k PAR	12			12
		894	291	312	291

of service based on the maximum capacity that could be needed *at one time*, rather than the grand total of all possible loads. In some situations, it may be safe to assume that not everything will be turned on simultaneously. However, one had better be very sure of this assessment and very clear in communicating to the DP and gaffer the limits of the planned rig (this would be a good thing to put in writing). You do not want to get caught short on power.

Once these determinations and calculations are complete, the gaffer knows all the equipment that will be needed for the rig: feeder cable, switchboards, dimmers, distro boxes, banded cable, extensions, DMX control cables, and so on. It is a good idea to order more than your initial calculations to allow for contingencies (and bad pieces that you will need to return). Better to return some equipment later than to not have what you need to complete the rig on schedule and have to order more.

Placement of distribution

Considerable thought goes into the placement of distribution boxes so that power is readily available and convenient. During filming, an electrician working the set should need only to glance around the immediate area to find power for a light, yet the cable must remain neat and invisible to the camera. An electrician rarely requires a 50-ft. stinger on a set that is properly cabled; a stinger should not have to cross a room if the distribution is effectively laid out. You should never find yourself having to run four or five stingers out a door and around a corner; one properly placed 100 A lunch box can eliminate a lot of mess, and task time. No matter how far away the gaffer wants a light, getting power should not create a crisis; cable should be standing by, ready to be run out to it.

Here are some rules of thumb for laying out set power on location and sound stages alike. Provide a “ring of fire”—surround the set with power on all sides. No matter where the camera is placed, you should have a 100 A gang box ready to pull in behind camera. In each room where action is to take

place, have 100 A whips (with gang boxes) coiled outside each door ready to come in when needed. In a room with only one door, provide 100 A whips on the opposite side of the room (through a window, through a rat hole in the set, over the top of the set wall, or dropped from the grid), ready to come in should the door have to close. Provide at least 100 A to each side of a room. In a large room, provide 100 A whips every 50 ft. (hidden outside windows, in side rooms, through rat holes, or ready to drop from the grid). In a house with a staircase, you need power at the top of the stairs. Hide cables that cross doorways by routing the cable up and over the top of the door. Work with the art department to create neat access points through the set wall like an air vent grill, or a removable wall panel.

RIGGING CABLE

During rigging, the distribution system remains disconnected from the power source and from the lights and electrical appliances. After the whole distribution system has been laid out and the system has been tested for continuity and shorts, the system can be connected to the power source and the main switch turned on.

In rigging, neatness counts. Keep the cables as out of the way as possible and well organized. A fire marshal or electrical inspector makes his or her initial assessment of safety from a quick look around at the general neatness of the work. If everything is nicely squared away, the inspector knows that it's unlikely that much will be found at fault on further inspection; if the work is sloppy and possible hazards are visible, the inspector is likely to keep looking for violations until they are found.

Cable is heavy and lifting and moving it can cause injury. Far too many lifetime electricians do not make it to retirement age because they wreck their backs. Some tips for how to avoid injuries are available on the *Set Lighting Technician's Handbook* Web site. Every electrician needs to adopt a policy of self-preservation. When lifting cable and heavy equipment, use two people whenever possible, even if it means waiting for someone to finish what they are doing to come assist you. OSHA regulations recommend a single person not lift any object greater than 60 lbs. alone. Don't carry cable; use carts whenever possible. Never jump off a lift gate with weight in your hands—it is murder on your knees. Enlist the help of the transportation department to use a stake bed truck to drop or pick up cable when making long cable runs along a street.

There is a natural desire among motivated individuals to always pull their weight. You don't want to be the guy who goes around picking up stingers, at wrap, while everybody else is coiling 4/0. We want to be someone who can keep up, or better yet, can outperform others. But, at the same time, we don't all look like the Green Bay Packers. Electricians come in all shapes and sizes, big and small, men and women, younger and older, compulsive and methodical. Even though there are these natural differences, people naturally try to conform to the culture and perceived expectations around them. So the example we do not want to set is one of competitiveness or one-upmanship, or manic speed that can lead to hasty actions and injuries—the same way we avoid leaving the hard work to someone else. We want to create an environment of teamwork in which we look out for one another, maintain reasonable expectations, and work smarter, not harder. If electricians, best boys, and gaffers create a culture that does not accept carrying 100 lbs on your shoulders as a safe practice, then workers will find ways to work smarter. The culture we create on set helps make the set safe for everyone.

Identifying cable, labeling circuits

When laying out single conductor cable, it is extremely important to identify each cable properly. At one time, motion picture lighting technicians relied solely on a system of knots made in the tie lines at each end of the cable (Figure 15.1). Today, each end of each cable must be identified with color-coded connectors or electrical tape. When using colored electrical tape, the code requires a 6-in. section of tape at each end of the cable. Fire marshals and electrical inspectors look for color-coding. They do not necessarily know anything about the knot system. Nonetheless lighting technicians still use knots as a backup. The knot system is valuable when the colors are hard to see, in dim lighting situations, or under sodium vapor lights. Tie the appropriate knots and color code both ends of each cable before uncoiling it.

Each spider box and distribution box should be labeled with 2-in. white tape. The label should include:

1. The power source (e.g., Generator #1 or Circuit #4 or Transformer #2).
2. The type of power—AC or DC and voltage (208/120 V AC, or 480 V AC or 240/120 V AC, or 240/120 V DC).
3. It is also helpful to identify the intended function of the circuit, such as "drop-in," "high box," "top lights," and so forth. A set lighting technician who is unfamiliar with the layout must be able to understand the circuitry by reading the labels on the cables and equipment.

When two different kinds of service are being used on the same set (such as 208/120 V AC, DC, or 480 V), make the difference immediately obvious by using different colored tape or different colored ink on the labels.

On spider boxes and distro boxes, identify the color of the hot legs with colored electrical tape or simply by writing red, blue, or black on a piece of tape. During filming, an electrician can immediately see what leg is being plugged into and tell the best boy if need be.

Each dimmer circuit has a number. When all the dimmers are on a single universe, the circuit number typically corresponds to a DMX512 address of the dimmer. Every cable between the dimmers and the lights is labeled with the circuit number, or in the case of Socapex cable, the range of circuit

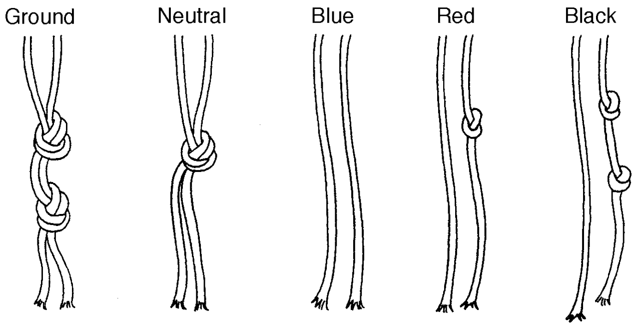

FIGURE 15.1

Knot system. Portable feeder cable comes with #8 sash cord tied at each end of cable, which is used to tie the cable coil for transport. These tie lines can also be used to identify the cables using this standard system of knots.

numbers (e.g., 1-6, 7-12). When rigging lots of dimmer circuits, affix white tape to both ends of all the cable before you run it. That way, it is an easy matter to mark the cable as you run it, and you need not carry tape around with you. Tab spare cable also so that it can be easily labeled when added.

Lacing cable

The conductors of a run of feeder cable are laced together as shown in Figure 15.2. This keeps the cables lying flat and straight, prevents the hazard of cable rolling under foot, and helps identify the cables that belong to one run from those of another. Many different runs of cable are often placed on a single catwalk. It is best to lay out the cables with any necessary turns in them before lacing them, and to lace them in shorter intervals in turns. Avoid sharp bends in cable. These cause hot points in

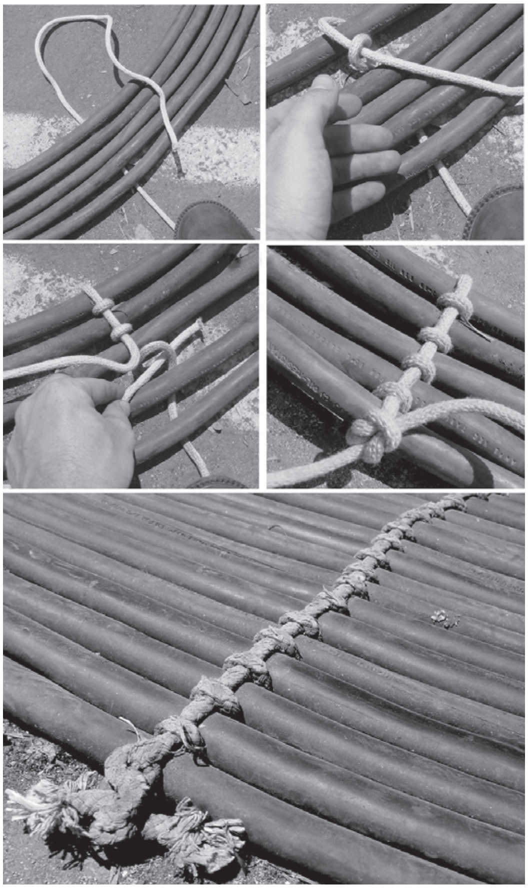

FIGURE 15.2

Lacing cable.

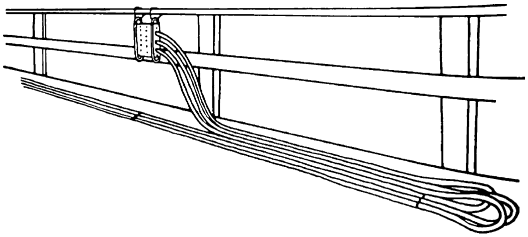

FIGURE 15.3

Extra length should not be coiled.

the cable. Never leave a live cable in a circular coil, because this can cause serious line loss and heat. Any excess cable should be left at the load end of the cable, where it will be available if needed later. In green beds and catwalks, excess cable should be run out in a straight line, turned back on itself, and run to its end point (Figure 15.3).

Ventilating and separating runs

If a large cable run crosses another large cable run, it is a good idea to use a bridge to separate them. Stacking one run of cable on top of another can cause problems that you might not anticipate. Not only do the two runs of cable heat each other by conducting and radiating heat, but the heat also increases the resistance of the cable, thus compounding the problem. Separating the cable runs also separates their magnetic fields. It is important to prevent conducting heat from one cable into another by keeping all cables surrounded by air, and never laying one run of cables directly on another.

Make first, break last

When cabling is added to or removed from a system, the ground connection is made first and broken last. This is called the *make first, break last rule*.

Connect in this order: (1) ground, (2) neutral, (3) phase wires.
Disconnect in this order: (1) phase wires, (2) neutral, (3) ground.

Cable should never be added or removed from a system when it is energized, but the make first, break last rule assures that in the event the system *is* energized a ground and neutral will be in place. Electricians should make it a habit to make connections in the proper order, regardless of whether the system is live. The idea is that if you get in the habit of doing it the right way every time, you'll be safe when it matters.

Traffic areas

Avoid running feeder cable on the floor of the soundstage across traffic areas. The stage floor is a freeway of pedestrian traffic and heavy equipment coming in and out: set pieces, forklifts, carts, and so on. It is best to rig these areas so they are completely free of cables, if at all possible. If a cable must cross the fire lane or other walkway, run it through a cable crossover. Cable crossovers

are constructed with channels for the cables that allow air space around the cable. However multiple crossovers placed side by side are murder to push carts across. Modular crossovers are available that lock together to create an extra wide crossover so that even large numbers of cables to be protected. It is not a good idea to cover cable with plywood or lauan, as this does not provide ventilation around the cable and has been known to start fires. It is better to run the cables up and over the walkway if possible. Grips can construct a bridge of truss, if no other appropriate structure exists.

Fire lanes

The space within 4 ft. of the outside walls of the sound stage is protected terrain and airspace. The fire codes require that a 4 ft. lane be kept clear of obstructions around the periphery of the stage. This has a very important and real purpose in the event of fire, heavy smoke, or blackout: to allow people inside the stage to feel their way out of the building without encountering harm. Ladders and similar gear should not be leaned against the outside walls where they could fall over and block the fire lane.

Fall protection

The area outside the protected rails of the catwalks in the perms is called the o-zone, The o-zone comprises an open structure of joists and beams. Do not venture out into the o-zone unless you are wearing proper fall protection equipment, and have the training to use it safely. Fall protection includes a full body harness, a "yo-yo" decelerator, and a system of properly rated attachment points that a worker can hook to. A worker who falls is decelerated and caught, but will end up dangling in the harness until rescued. O-zone work is typically the jurisdiction of the grip department.

Root out bad contacts

Each time you attach two pieces of cable, check the pins and be sure that each connector is making solid contact. Use a pin-splitter tool to bend apart smooshed pins. Nightmarish flicker problems are caused by bad, bent contacts in Bates cable. Having to track down a bad cable because lights start flickering during filming is a horrible experience—banks of lights go dark one after another as the crew scrambles around behind the sets yelling, "Repatch"—it's the kind of thing that makes grown men want to cry. Any questionable cable should be put aside and tagged boldly with tape.

Waterfalls and Cable Drops

The typical strategy for cabling standing sets is to run feeder cable and dimmer circuits up into the perms, and from there distribute the power to boxes above the set in the perms and green beds. These boxes feed lights that are rigged above the set, suspended on truss or pipe, or mounted to the green beds. The cable also runs to strategic locations above the set (above each corner of the set, for example), then drops to the stage floor to power floor-level distribution boxes. Edison lunch boxes or Socapex dim lines may be rigged to "drop in" on rope so they can come in, or pulled up out of the way as needed.

A waterfall is a vertical run of cable going up to the perms, or coming back down. It may be made up of 4/0 feeder cable, Socapex, or 60 or 100 A dimmer lines coming from the dimmer shack. It can be hard to replace a piece of cable once it is rigged in a waterfall. With Socapex cable

Table 15.2 Weight of cable

Cable	Weight (lbs/ft.)
4/0	0.96
2/0	0.68
4-wire banded (#2)	1.33
5-wire banded (#2)	1.70
100 A (#4)	0.72
60 A (#6)	0.55
Multiconductor (Socapex)	0.75

especially, it is a good idea to rig a spare cable or two into the waterfall from the get-go, so it is already threaded into the dimmer room and up to the perms.

The rigging gaffer has to determine how much weight a proposed waterfall will put on the structure and work with the rigging grips to provide adequate support. Table 15.2 gives the weight per foot in lbs of common cables.

Table 15.3 shows an example of how to use these figures to make a load calculation for a waterfall that has a 40-ft. drop.

$$\text{Weight of waterfall} = (\text{number of cables}) \times (\text{weight per ft.}) \times \text{drop in ft.}$$

Table 15.3 Example of waterfall cable weight calculation

Number of cables	Cable type	Weight per foot	Drop (ft.)	Total (lbs)
32	4/0	0.96	40	1229
24	100 A	0.72	40	691
10	Socapex	0.75	40	300
				Total 2220 lbs

That is over 1 ton of cable. With a large waterfall, like this one, the grips would be called upon to rig a suitable member to the building structure. A piece of truss works well for this purpose, sitting atop and spanning the beams of the perms. A load like this would also need to be cleared with a building engineer. The truss must be secured so that it will not roll, and be of appropriate size and strength. To give a point of reference, one manufacturer's 10-ft. piece of 12-in. light-duty box truss can support a center-point (undistributed) load of 2231 lbs. (This is a worst-case figure. The cable would naturally be distributed along the truss, which increases the capacity figure. When the load is distributed evenly along the length of the truss, it has a capacity of 4460 lbs.)

A waterfall is rigged by hoisting each cable by one end up to the perms. For hoisting, the line is attached to the end of the cable, as shown in (Figure 15.4). Once hoisted, each cable is tied off to a structural member. Cables are secured by tying a binding knot such as a clove hitch around the cable (Figure 15.5) and tying off to the supporting member with a bend, such as a square knot. If a clove

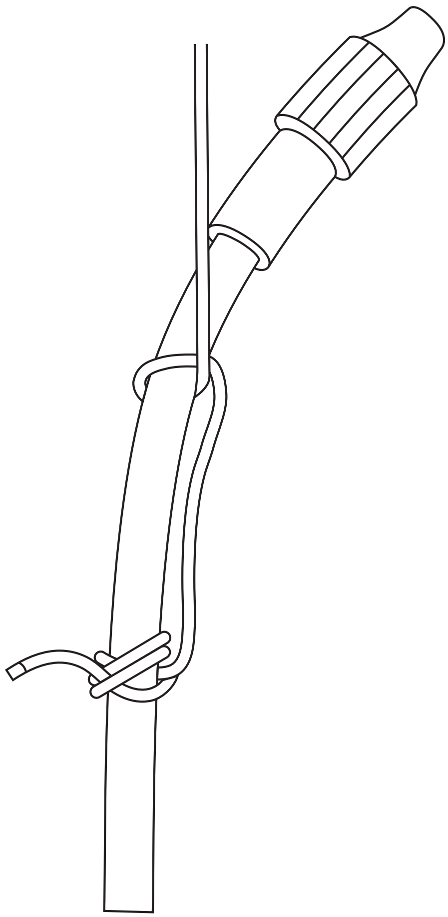

FIGURE 15.4

A binding knot a couple feet from the end of the cable (a rolling hitch is shown here), and one or two half hitches around the cable end help ensure that the cable will not slip when hoisted.

hitch is used, be sure that the knot is on the underside of the cable so that the weight of the cable tightens the clove hitch around the cable and will not let it slip.

When tying off an individual cable drop from a catwalk or green bed, tie the cable to the knee rail or standing post. Do not tie off to wood smaller than a 2×4.

Knots for rigging

For our purposes, we can think of knots in three general categories: loop knots, hitches, and bends. A *loop knot* is one that provides a closed loop such as might be used to tie a line to a light to hoist it. A *hitch* is a knot used to tie off a rope to a fixed object, or to tie a rope around an item so that the rope conforms to the item to which it is tied, and may even constrict or bind so as to make a tight

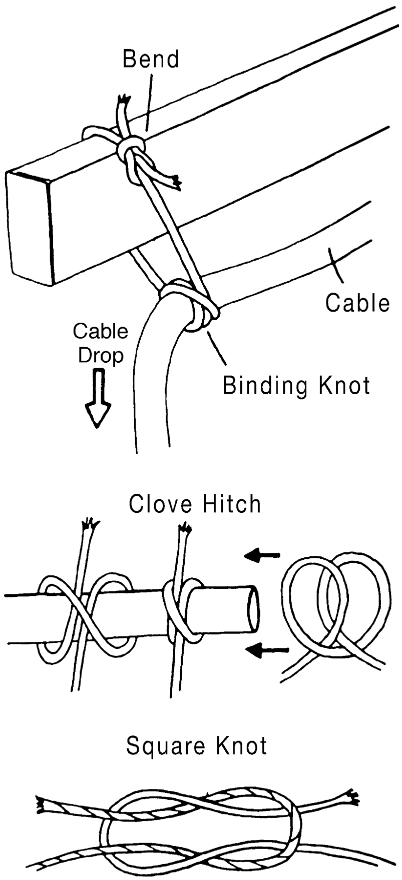

FIGURE 15.5

When tying off a cable drop, a binding knot is used to grip the cable, and a secure bend secures the line to the rail. A clove hitch and square are commonly used for this, but there are stronger, more secure knots for these tasks.

hold on the item when under tension, such as a vertically hanging cable. A *bend* is a knot that ties one line to another line, such as when passing the two loose ends of the tie-line around the post and tying them together. In each category there are different knots that might be used. Depending on the situation, certain knots provide specific advantages. A rigger needs to learn a variety of knots, and know which knot will be safe and secure for a particular application, which will be easy to adjust or untie, and which will not.

To be reliable, a knot needs to be tied correctly, and dressed and set properly. *Dressing a knot* means making sure that the knot is formed correctly and that the lines pass out of the knot in the correct way. If a knot is not dressed properly, it can capsize or deform under tension. *Setting a knot* means tightening the working elements of the knot, often by pulling on the working end of the rope, so that the knot cannot be shaken loose.

Loop Knots

Bowline: A bowline is commonly used to tie the rope to the equipment for hoisting or hanging (Figure 15.6). The bowline is generally pretty strong and secure. However, if the bowline is tied incorrectly, or is dressed improperly, it can fail. A bowline can be tied to create a loop (Figure 15.6A); it can be tied around an object (Figure 15.6B).

Bowline on a bight: A bowline on a bight (Figure 15.6C) is a loop knot one can tie in the middle of a rope. It makes a pair of fixed loops that will not slip. We sometimes use this knot to suspend a light from two points. The lighting technician attaches the loop to the light by passing the rope through the yoke, hooking the loops over the pin, then tying the two half hitches over the loop on the pin with the standing end of the rope. You can maneuver the light into place by pulling the ends from two different pick points. A bowline on a bight can also be used to form the loop for a trucker's hitch, and it will not jam.

Alpine butterfly: The Alpine Butterfly (Figure 15.6D) is a loop knot that can be used in the same manner as a bowline. It is considered a very strong and secure knot, superior to a bowline. It is easy to tie and is considered robust – it is hard to tie incorrectly, or in a way that might fail.

Binding Hitches

Clove hitch: A clove hitch is commonly used to tie a line to a cable, either to suspend a cable drop, or simply as a tie-line for the cable. The weight of the cable makes the knot grip the cable more tightly. A clove hitch (Figure 15.5) is very simple to tie, but it is not considered as reliable as other binding knots offered below. In order for the knot to constrict around the cable, the knot must be oriented so that the rope passes around the far side of the cable first, and not oriented such that the lines converge into the knot before they pass around the cable.

Prusik: A Prusik is a friction knot that can be used like a clove hitch. When weight is put on the knot, the knot binds tighter. The Prusik hitch has the advantage that the position of the knot can be easily adjusted after the knot is tied; when weight is taken off the knot, the knot can be easily slid up or down the cable. (Figure 15.7A).

Rolling Hitch: A rolling hitch (Figure 15.7B) is considered stronger than a clove hitch, yet comes out fairly easily.

Constrictor Knot: A constrictor knot is considered the most secure of all binding knots. To tie a constrictor knot, start with a clove hitch, but then bring the end of the line back through the first turn as shown in Figure 15.7C. This knot can be difficult to untie once it has been under load.

Other Hitches

High safety knot: A high safety knot is used to tie off a line that has tension on it, such as that from a dead weight. The *saddle* cinches the line so that it will not slip while you tie the two half hitches to secure it (Figure 15.8). People who do not know knots often resort to making a single turn, with two half hitches (like the High Safety knot, but without the saddle). A single turn with two half hitches is not considered a very strong knot. In tests, the knot will always fail before the rope.

Highwayman's hitch or draw hitch: A highwayman's hitch is a "quick release" knot. It is very handy for securing a light load temporarily, such that the knot can be removed very quickly by pulling the loose end (Figure 15.9). It is not considered a strong or secure knot because it can be shaken loose. Be sure the knot is properly set (by pulling the standing line (F) to snug the knot tight).

Trucker's hitch: There are various ways to make a trucker's hitch. The basic idea is to form a loop in the rope, and use the loop to gain mechanical advantage to pull the rope tight. You would want

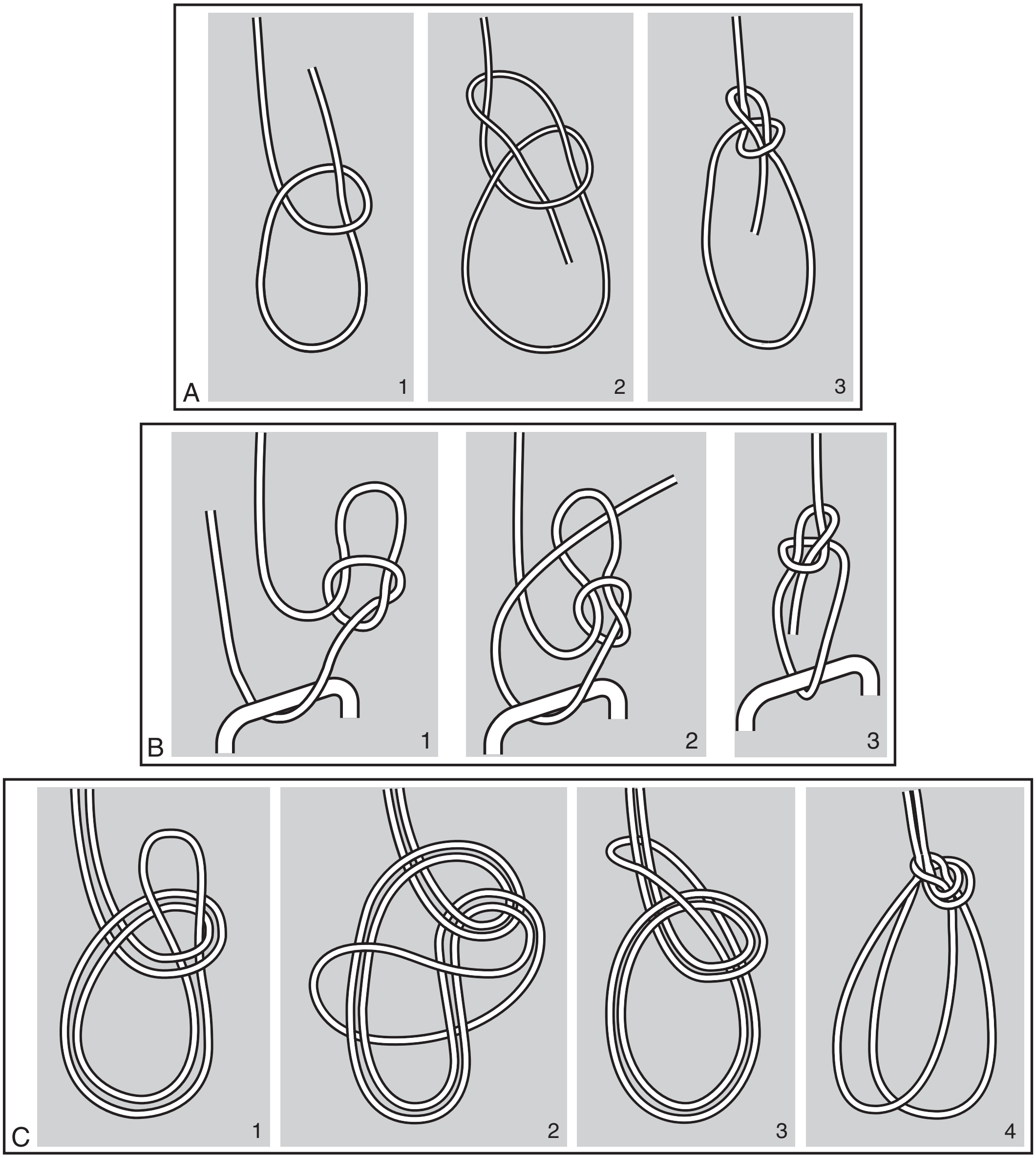

FIGURE 15.6

Loop knots. (A) A bowline. People often remember the bowline using a little narrative: the rabbit comes out of the hole (step 1), goes around the tree (step 2), and goes back into the hole. Note that the loose end is dressed to the inside of the loop. (B) A bowline can be tied around an object. (C) A bowline on a bight is a bowline made in the middle of a line, which provides two loops.

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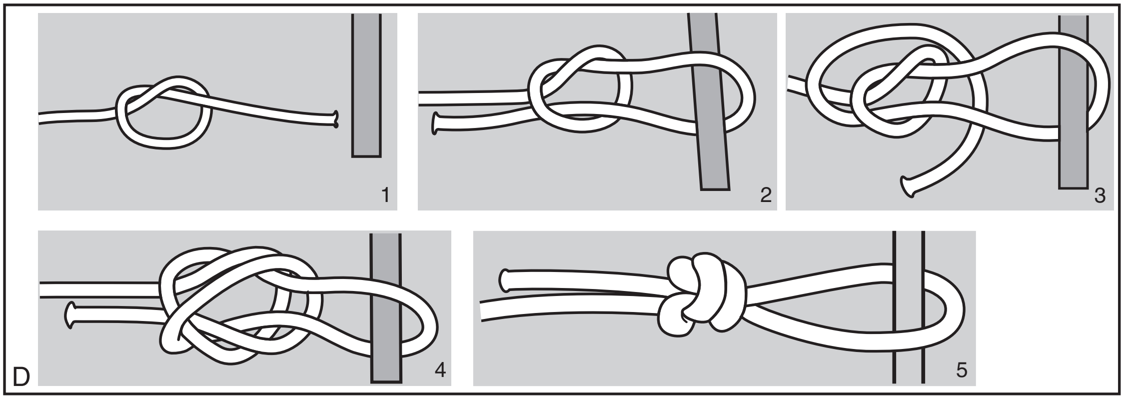

FIGURE 15.6—Cont'd

(D) An Alpine Butterfly is a stronger, more secure loop knot.

to use a trucker's hitch for example, when tying something down or securing a rope around equipment to hold it during travel. The easy way to make a trucker's hitch is to form a loop (by tying a bowline on a bight, or by creating a bend in the rope, and then tying a half hitch or figure-8 knot into the bend). Take a turn around a sturdy post or rail with the loose end, then thread it back through the loop and use the loop like a pulley to cinch the rope tight. The loop knot will often jam and be very hard to untie once it has been under load. (A figure-8 is easier to remove than a half hitch. A bowline on a bight is better still). The hitch shown in Figure 15.10 is less secure, but it comes out very easily when loosened.

Bends

A bend is a knot used to tie two ropes to one another. The ones discussed here are intended for ropes of equal size. We commonly use a bend to tie cables to structural members, as was shown in Figure 15.5.

Square knot: A square knot is very commonly used for this purpose, but as bends go, it is not actually considered a very strong or secure knot. Although a square knot serves in many situations, when a knot is under considerable load it is worth knowing a stronger knot. To remember how to tie it there is an old rhyme that goes "Right over left, left over right, makes a knot both tidy and tight." A common mistake is to tie right over left and right over left again. This makes a granny knot, which is a very poor knot that *will* come loose under tension. You can tell if you have made the knot correctly by its symmetry (Figure 15.5).

Alpine Butterfly Bend: This is a simple knot to remember and easy to tie. It is considered one of the strongest and most secure knots, and is as easy to remove as any other bend. (Figure 15.11A).

Flemish bend or figure eight bend: A Flemish bend (Figure 15.11B) is considered a very strong bend, and can be removed more easily than half hitches. It is basically a figure eight knot in one rope, with a second rope rethreaded back through the figure eight. A figure eight bend can also be used to make a loop knot by making a figure eight knot in a rope, then rethreading the lose end of a rope back through the figure eight. This is considered at least as strong a loop knot as a bowline. (There is also another simpler way to make a bend using a figure eight knot, but it is not considered as secure a knot when the two ropes pull in opposite directions. It is made by simply holding the ends of two lines side by side and tying them in a figure eight knot.)

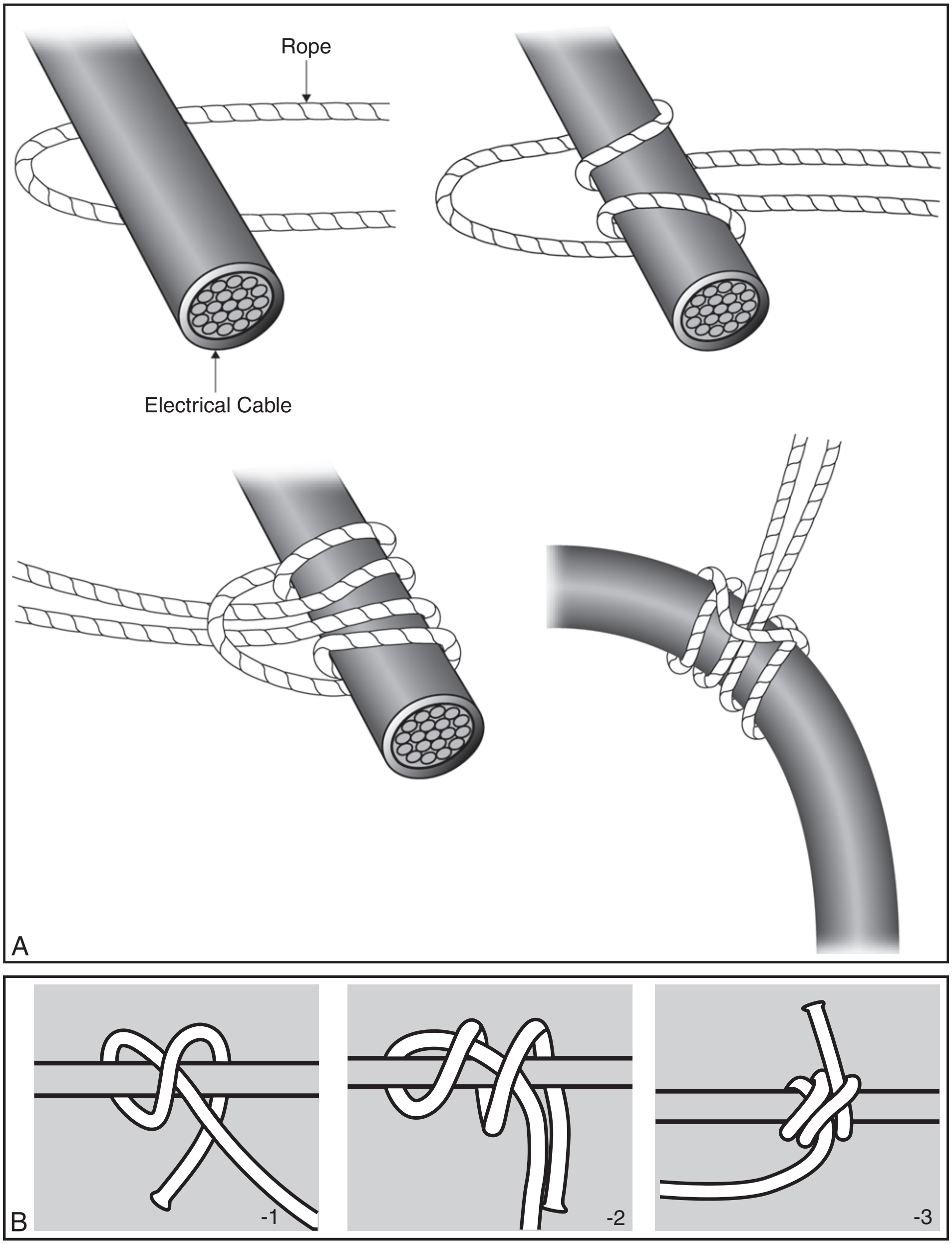

FIGURE 15.7

(A) The Prusik is a good binding knot for tying off cable. (B) A rolling hitch is considered more secure than a simple clove hitch.

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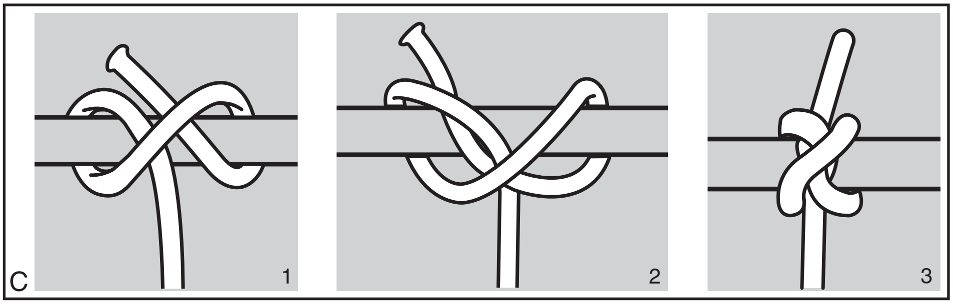

FIGURE 15.7—Cont'd

(C) A constrictor knot is considered the most secure of the binding knots, but it can be hard to untie.

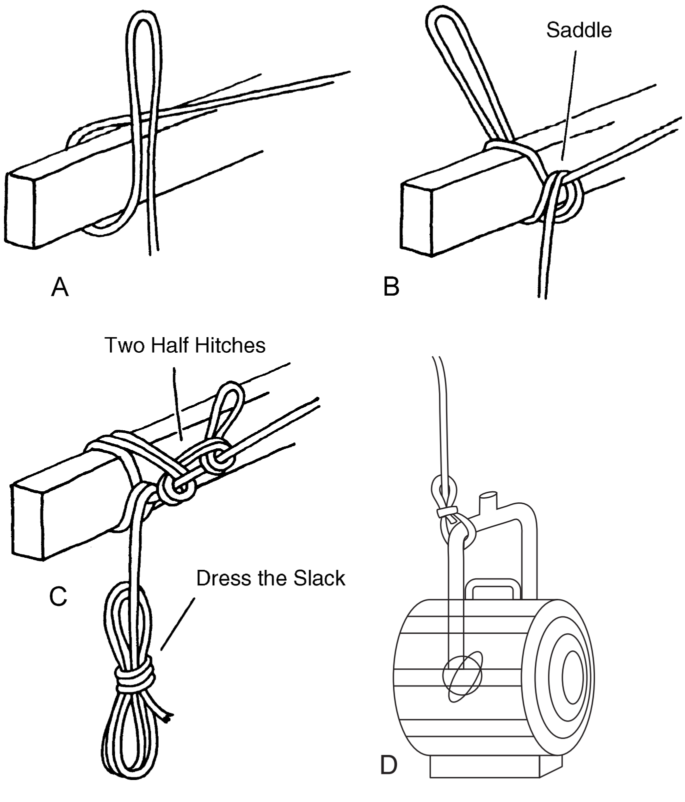

FIGURE 15.8

High safety knot.

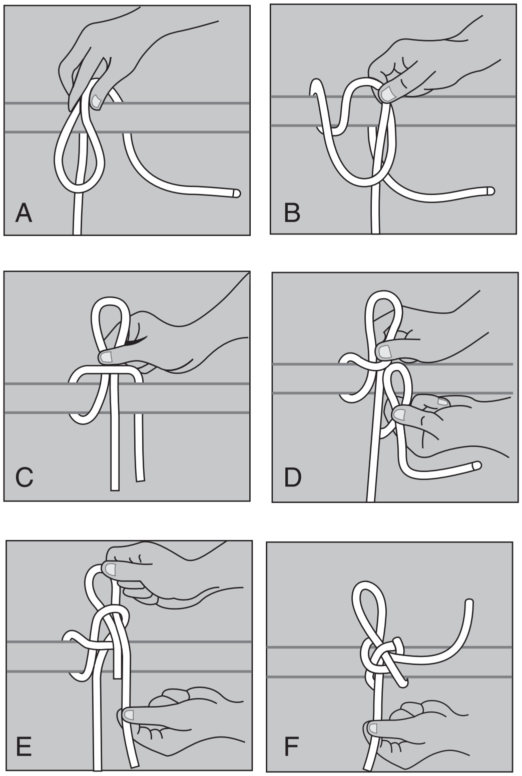

FIGURE 15.9

The highwayman's hitch is easy to untie by simply pulling on the loose end.

Strength of rope

The strength of rope being used to hang or hoist equipment is dependent on a number of factors, the primary ones being: the type of knot you tie, the age and condition of the rope, the type of rope, and the thickness of the rope. The *tensile strength* (or break strength) of a rope is the breaking point of the rope when it is brand new under a static load and when no knots are used. Rope manufacturers use this figure to work out a recommended *work load limit* (WLL), the load limit that can be routinely put on the rope in straight tension, and allows a margin of safety and longevity of the line. The WLL is typically 10-25% of the tensile strength, depending on the type of material and use. (For climbing and rescue operations, the WLL is no more than 10% of the tensile strength.) The WLL should never be exceeded, even when the rope is new.

A static load is one that just hangs. No load is purely static in reality. When the rope is tugged by the sudden addition of a load, or a sudden stop or start while raising or lowering the load, or if something swings on a rope the load changes constantly—this is *dynamic loading*. Dynamic loading can

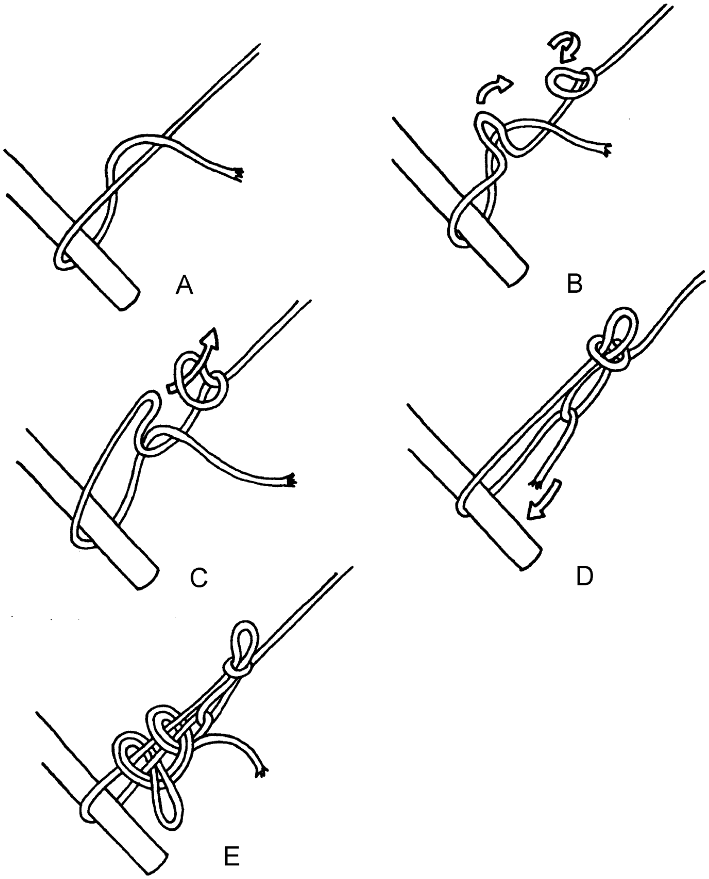

FIGURE 15.10

A trucker's hitch is great to cinching the rope down tight. The version shown here is meant to come out very easily by simply untying the two half hitches and taking the tension off the line. This version is not a terribly strong or secure knot because it relies on constant tension and can be easily shaken out or pulled out if heavily loaded. This one is a great knot for tensioning a taught line.

easily require a rope 10 times as strong as a static load. If the line is used to arrest the fall an object, the dynamic load is much, much higher, and depends on how far the object is allowed to fall before being caught.

A knot in a line decreases the strength of the line at that point. This reduction in strength varies with the type of knot, and the type of rope, but riggers will typically rate a rope to 50% of its nominal strength to account for loss of strength due to knots. Tests indicate that a bowline may retain around 65% of its initial strength, a figure eight bend (or bight) around 75%, and a butterfly knot as much as 80% of its initial strength, but bends such as a fisherman's knot or sheet bend are weakened to

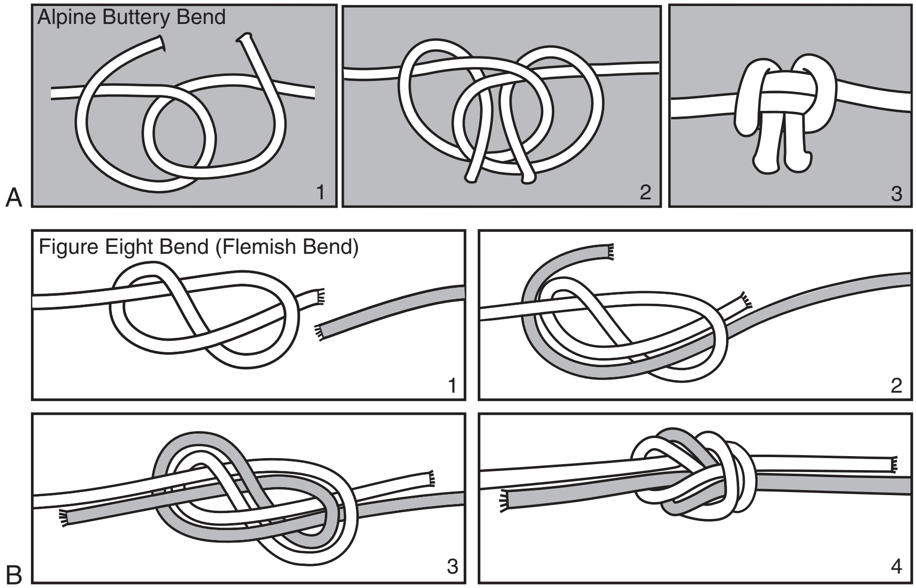

FIGURE 15.11

Bends are knots used to tie one line to another. (A) Alpine Butterfly Bend. (B) Figure eight bend (Flemish bend).

around 50% of their initial strength.[1] Square knots are not even considered. A particular ½-in. manila rope has a tensile strength of 2380 lbs, its WLL is 264 lbs (roughly 11% of tensile strength). If the rope has knot in it with a 50% strength factor, then the maximum static load would be 132 lbs (50% of 264).

One manufacturer's recommended work load limits for manila rope are as follows (check the label on the box for the actual limits of the rope you are using):

1/4 in.	54 lbs
3/8 in.	122 lbs
1/2 in.	264 lbs
5/8 in.	496 lbs
3/4 in.	695 lbs

Finally, the strength of a line depends on age, wear, and exposure to heat and sunlight. Three-strand twisted manila rope, commonly called hemp or jute, is an inexpensive natural fiber rope

[1]These are rough figures summarized from a great deal of data compiled from tests conducted by the Cordage Institute. There are many variables involved, so these figures should not be used for any kind of calculations. This summary is meant to give the reader a general impression of the variance.

that is widely used in our industry. Manila rope holds knots well (synthetic ropes are more slippery), and it will not melt. However, manila rope will degrade over time, especially when subjected to heat in the perms, or sunlight. It works just great for most of our applications, but when a rig stays in place for a year or more with the rope constantly under load, another type of rope should be used. Hemp will eventually weaken and part (break). Chain or aircraft cable safeties should always be used, and hemp ropes should be replaced from time to time. Hemp rope should not be recycled for any load-bearing function. Use new rope.

Other types of rope each have specific advantages. Nylon, polyester, Dacron, and pro-manila (a higher quality look-alike) all offer better tensile strength and are better able to withstand shock, as well as heat and sunlight. For specific applications, a more expensive rope may offer advantages. Check out rope manufacturers' Web sites for more information.

RIGGING LIGHTS

Lights hung up high are commonly mounted to truss, pipe (1½-in. IPS (1.9-in. OD) schedule 40 steel pipe), or speed rail (aluminum pipe), or suspended using a trapeze. When hanging lights above the set:

- Always leave two loops of slack cable at each head so that it can be panned and tilted and moved if needed.
- Cables are sashed neatly to the pipe at regular intervals.
- Each light should be labeled in such a way that the label is visible from below, so that the light's identification (number or letter) can be called out during production. Label the power cord with the same number for easy patching.
- Be sure that the light's power switch is on. Lights that are suspended up high are typically controlled remotely using dimmers or remote switches.
- Tighten all the nuts on the C-clamp so that the light is properly locked off.
- Every light must have a safety cable looped through the bail and over the pipe to prevent the light from falling if it comes loose. Accessories such as barn doors or chimeras should also have a safety cable. Smaller lights typically use aircraft cable; larger ones may use nylon webbing or chain (Figure 15.12).
- Don't wear a tool belt, and keep the tools you must carry to a minimum. Tie off any tools you carry to your waist belt so they cannot fall and hurt someone below.

Truss and pipe may be dead-hung on chain, or suspended using chain motors. When the pipe or truss is dead-hung out of easy reach, lights are hung using a ladder or a lift such as a scissor lift, boom lift, or articulated boom lift. An articulated boom can reach over the top of sets in places that are otherwise impossible to get to. With chain motors, the rig can be raised and lowered from a central chain motor controller. When floor space is available, it is very convenient to be able to bring the truss down to about a 5-ft. working height, mount the lights and tie off the power cords, then raise the truss into position on the chain motors. A single light on a trapeze may be raised the old- fashioned way with block and tackle. Figure 15.13 shows the mechanical advantage gained by using different configurations of pulleys.

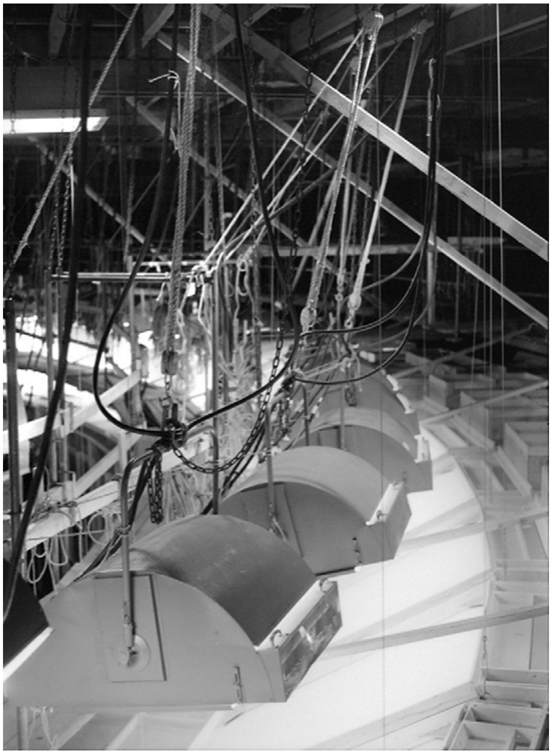

FIGURE 15.12

A row of eight-banger soft lights shine down through the ceiling of the set, rigged to the perms with blocks and tackle. This rig creates a soft top light for a three-level set built for *Star Trek: Deep Space Nine* on stage 17 at Paramount Studios. Note that the blocks and tackle are tied off to the handrail with high safety knots. In addition, each light is tied off with guy lines and secured with chain.

(Rig by Frank Valdez, photo by author.)

Weight-loading chain motors truss and pipe

Weight calculations are necessary when a lot of lights or cable are to be suspended. Sizing and hanging the truss and chain motors is typically done by the grip department; however, they may need to be supplied with the weight information of our equipment, and the grips work with the rigging gaffer on exact placement of the chain motors. Weight information for many lights is provided at the *Set Lighting Technician's Handbook* Web site, and also on manufacturers' Web sites. Chain motors we commonly use are rated per motor for 300, 1000, or 2000 lbs. The weight per foot of common cable is given in Table 15.2.

Although the grip department makes these calculations, it is important for everyone in set lighting to appreciate the dynamics of weight loading. The load over the span of a piece of truss or pipe is not necessarily uniform from one chain to another even when the weight on the truss is uniformly

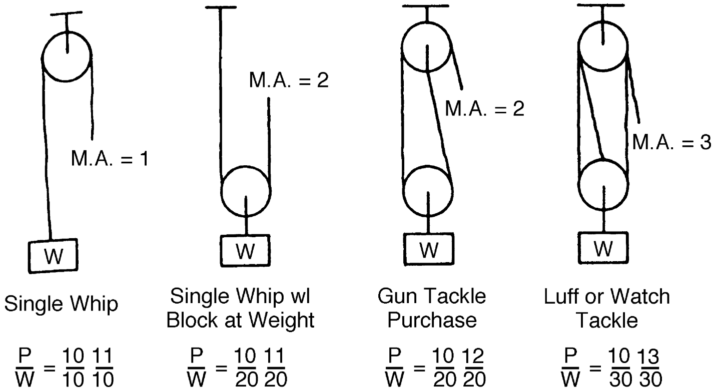

FIGURE 15.13

Block and tackle mechanical advantage configurations. The moving part of the block and pulley is called the sheave. Heavy lights, like the eight-bangers shown in Figure 15.12, are rigged with the luff tackle, which gives a three-to-one mechanical advantage. Smaller lights could have a single whip with no mechanical advantage. Reprinted with permission from Backstage Handbook by Paul Carter (New York: Broadway Press, 1988).

distributed. Figure 15.14 shows the load factor carried by each of the chains when the truss is supported from two points, three points, four points, and five points. Note that the single greatest percentage of weight occurs when a piece of truss or pipe is supported from *three* points. In this configuration, the center point has a load factor of 0.625; in other words, it takes 62.5% of the load, and the end points each only take 18.75% each. The total load factor (1) equals the sum of the three (0.1875 + 0.625 + 0.8175 = 1). Note that supporting the truss from two pick points, as shown in the upper right diagram, supports the truss at three attachment points with lighter loading (0.5 x W vs. 0.625 x W) than using three pick points.

All load calculations depend on the pipe or truss hanging horizontally. If one end of the truss is raised higher than the other, all loads shift. The speed of all the chain motors should be matched to avoid raising one end faster than the other and creating an out-of-balance situation.

Truss and pipe also have published weight capacities. There are too many different types of truss and pipe to attempt to list them here, but you can get these data from your supplier, or the manufacturer.

Testing

Once the entire distribution system is in place, it must be thoroughly wrung out; that is, each circuit from beginning to end must be tested for short circuits, continuity, correct voltage (120, 208, or 240), and line loss. In the process of testing, you may find blown fuses, tripped circuit breakers, blown bulbs, bad connections, burnt-out cable, and the like. By the time you are finished, you have a pristine rig ready for the shooting crew.

Next, plug in all the lights and begin to turn them on. *Check that each light is working.*

With all the lights on, use a precise voltmeter to *check for line loss*. First check the voltage at the power source, and then check it at the end of each run. Be sure that you are checking at the farthest

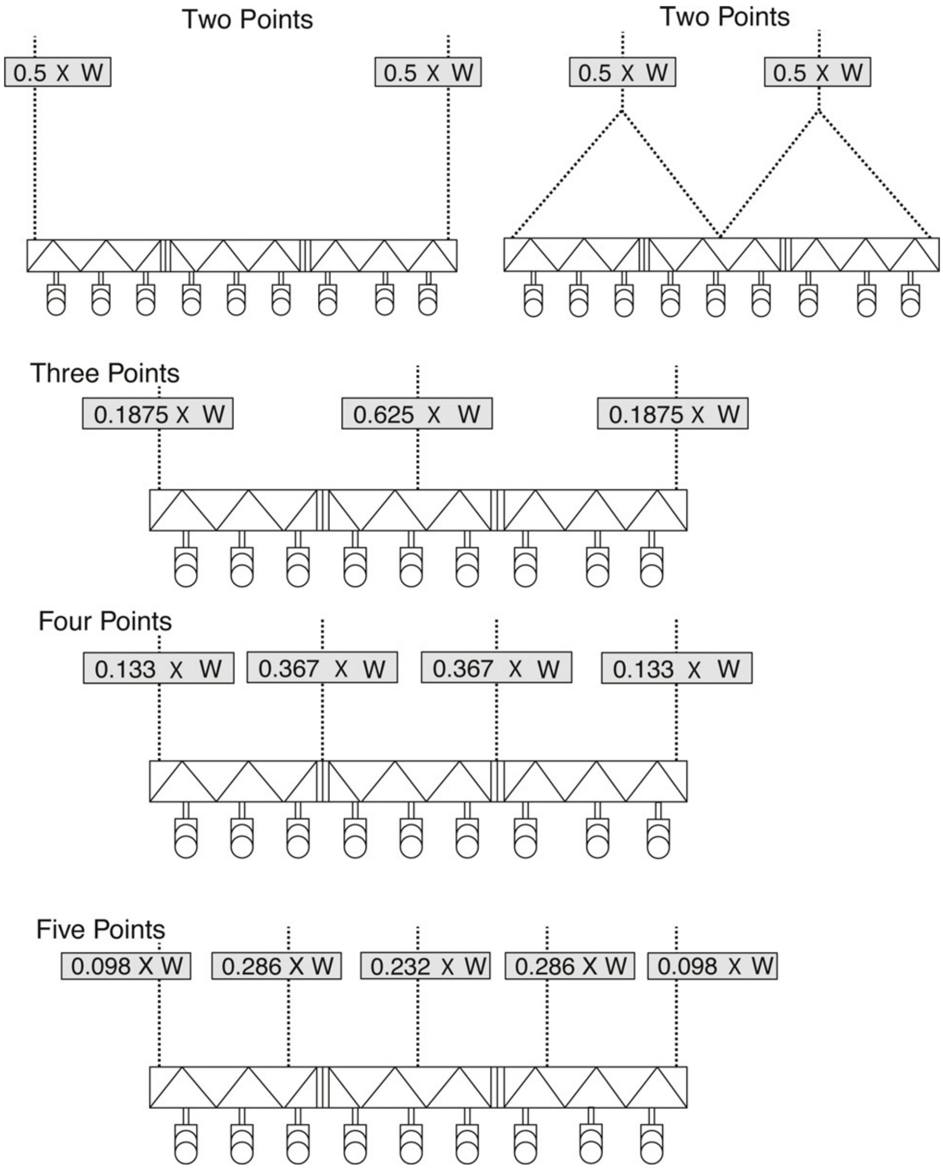

FIGURE 15.14

The weight carried by each chain is not the same.The weight carried by each point can be found by multiplying the total weight of the load (truss, lights, and cable) by the load factor shown here for each pick point. The load factor of each pick point changes with the numbers of points. This assumes that the weight of the lights cable and truss are distributed evenly along a length of truss.

point from the power source on each run. If the line voltage is abnormally low, check for bad connections and bad cable on that run. Remember resistance increases as the load increases, so a voltage test tells you nothing about the line loss unless you are operating at or near the full load you expect to have.

If magnetic HMI ballasts are to be used, *check the line frequency*. It should be constant at 60 Hz.

RIGGING LIGHTS AND CABLE IN AERIAL LIFTS

Rigging lights to an aerial lifts is a common task for rigging crews. A complete description of aerial lift operations is available at the *Set Lighting Technician's Handbook* Web site; however, the rigging aspect is covered here. Driving heavy machinery requires proper training. Additional training is required to make load calculations for placing loads on the basket of an aerial lift using calculation methods provided by the lift manufacturers. You can find out more about training programs at the *Set Lighting Technician's Handbook* Web site.

Mounts

Various manufacturers make hardware for securely mounting large lights to the basket of an aerial lift. The grips that rig the mount need an idea of which way the light will face to position the mount conveniently. There are two basic types of mounts: candlesticks and T-bar Condor brackets used to mount large lights.

A *candlestick* is a solid iron pipe with a junior-size receiver in one end. The pipe is mounted inside the basket to the vertical posts of the guardrail using chain vice grips with the T-handle facing the operator (Figure 15.15). (Bazookas, junior risers, and lights stands should not be used for big lights. The castings are not strong enough and will split. Only solid metal candlesticks should be used.)

A *T-bar* consists of two vertical posts that hold a horizontal mounting bar just above the top guardrail. Junior mounts can be slid around the horizontal mount to support lights. The vertical posts are attached to the guardrail posts using chain vice grips or U-brackets and bolts. Some people prefer to use chain vice grips, because they wrap around the tubular guardrails (distributing the pressure more evenly) and have less of a tendency to crush them. If you use U-brackets, don't overdo it; tightening the brackets until they crush the tubular posts does nothing to increase the strength of the rig.

When an 80-ft. arm is resting on the ground, the light mounts are still 6 ft. above ground level. This makes mounting big heavy lights from ground level a challenge. The best way to mount lights onto a Condor mount is to work from the lift gate of a stake bed or other truck. Two electricians can lift a light into place from a lift gate. If no lift gate is available, you can mount the light by tilting the basket forward so that it is easy to reach from the ground. Lift the light onto the mount. Then, while two people hold the weight of the light, hook a safety line from the back of the light to the inside guard rail and tighten it until it takes up the weight of the light. This keeps torque off the junior pin, which is not strong enough to withstand the weight at right angles. With someone stabilizing the light, tilt the basket back to level.

Always tie a safety around the bail to the basket. The safety should be 1-in. tubular webbing. A 10-ft. length is sufficient to run a loop through the knee rail and over the yoke with plenty of slack for maneuvering the light. Loop the safety around the knee rail so that if the light falls, it will swing *under* the basket and not smash into it.

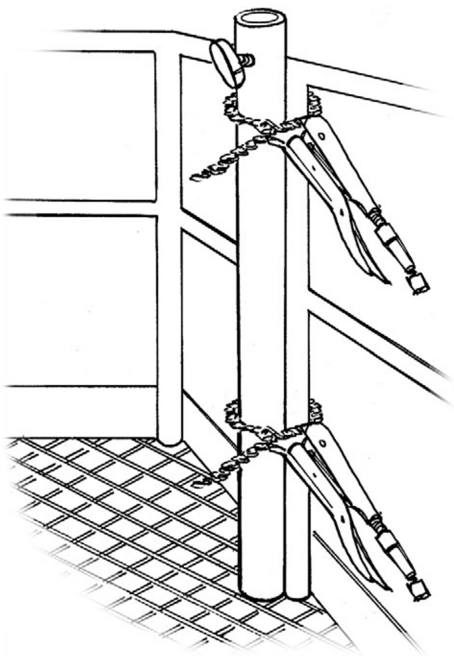

FIGURE 15.15

Vice grips used to mount a candlestick. Note that the chain vice grips are rigged so that they do not stick out and create a hazard.

Once the lights are rigged on the basket, the operator must use a light touch on the controls and operate the chassis and boom as smoothly as possible. Jerking the lights around with abrupt movements puts a great deal of stress on the mounts.

Grip equipment, such as a four-by gel frame, can be secured out in front of the light using ear extensions (Figure 15.16A) or a grip helper (Figure 15.16B).

A meat ax is commonly secured to the rail of the basket to provide a means of manipulating nets and flags out in front of the light. A cut is often needed. The grips supply additional flags and nets tied to the basket in case they are needed once you are aloft.

In some circumstances, the shot requires that the lights undersling below the basket. This does not present any real problems in terms of rigging; however, it does make it impossible to operate the lights from the basket. Either a light with an automated yoke must be used (see Chapter 11) or a second lift must be used to focus and adjust the lights.

Cabling

Figure 15.17 illustrates how to support and control cables. The head cable must be long enough to reach the ground when the boom is at its full height. Extend the arm out fully at ground level. A head

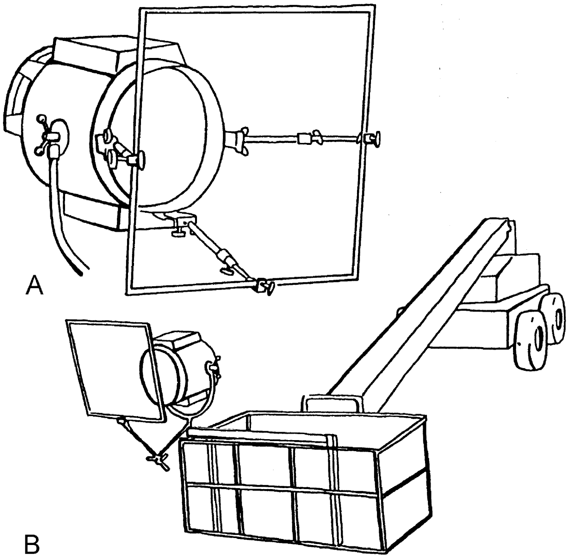

FIGURE 15.16

(A) Ear extensions. (B) Grip helper and Condor bracket.

cable extension is usually required to make the run. As always, the head cable should have a strain relief at the head. Leave enough slack head cable so that the fixture can be maneuvered. Tie off the cable to the middle rail, running it around the basket to the center of the basket next to the lift's controls. When there is more than one cable, run all cables together in a single bundle. Tie the cables off to the basket where they exit the basket. Run the cables down to the top of the arm and, leaving enough slack so the basket can be fully rotated left and right, tie off the cables to the top of the arm.

At the end of the second telescoping section, the cable needs to be supported. Rigging gaffers often strap a boat roller at this point in the arm using webbing. The roller supports the cable but allows it to freely pay out as necessary. You can also support the cable with a loop of line hung loosely around the cables and tie the line securely around the arm (be sure to position the line so that it stays clear of the moving parts). As the arm extends and retracts, you want the cables to pull freely through this boat roller or loop. The junction between head feeder cables should be tied securely with a strain relief and always remain below the loop.

Usually, only one loop or roller is required. The remainder of the cable can be controlled from the ground by tying a ½-in. line to the cable about one-third of the way up. The spotter on the ground uses this line to help control the cables when the arm is moving. Once the arm is set, the line is tied off to the chassis, holding the cables taught along the arm. Always have a ground spotter present when a rigged Condor arm is in motion.

Never place HMI ballasts and distribution boxes behind or in front of the chassis. If you need to move the chassis, this causes delay. In the worst case, you could run it over.

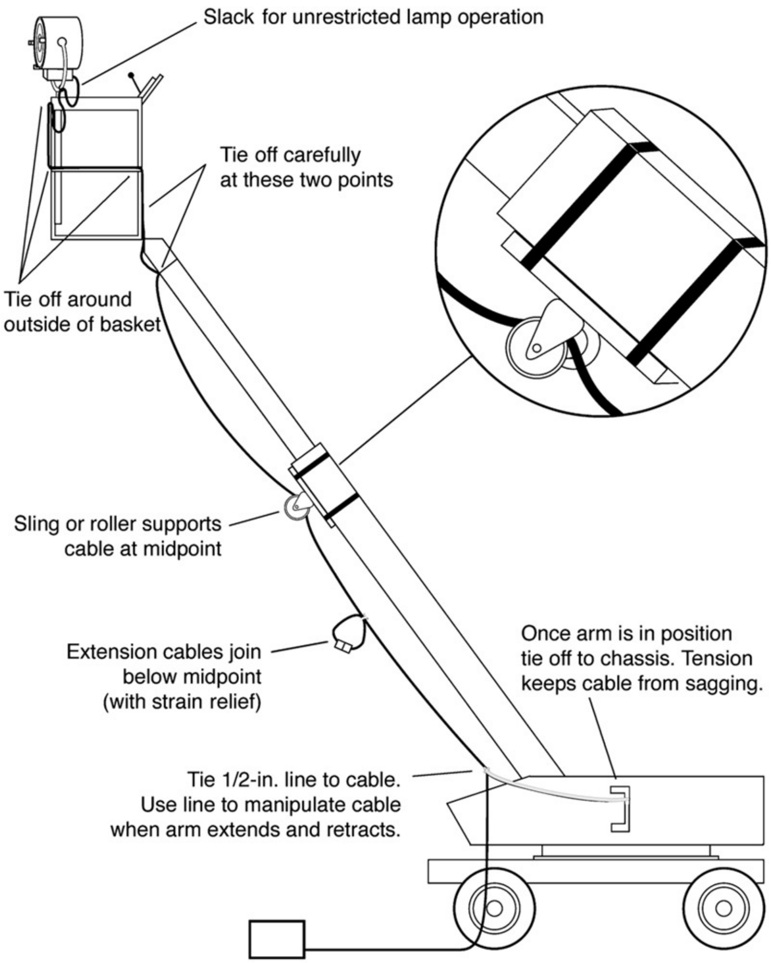

FIGURE 15.17

Cabling the arm.

Condor duty

An evening of "Condor duty" is made up of a period of rigging (preferably in daylight), a period of positioning the arm and focusing the lights (usually as night falls), occasional radio calls to refocus, and long hours of sitting at the top of the lift doing nothing. Make yourself comfortable and stay warm. Square away the following items in the basket well before it is time to take the Condor up:

- Walkie-talkie
- Tools (only what you need, and secured so they cannot fall)
- 100-ft. tag line (to pull things up to the basket)

- Furniture blankets (to sit on)
- Apple boxes (to sit on)
- A reading and work light
- Layers of additional clothing
- Warm gloves and hat
- Snacks and drinks
- A good book (this book, for example!)

Once in position, some people like to drape furniture pads or duvetyn around the sides of the basket and put rubber matting on the floor of the basket as protection from the wind. You can construct a very comfortable chair with one furniture blanket and seven to nine large grip clips. Use three grip clips to clamp one edge of the blanket to the top rail on the narrow side of the basket. This will be the back of the chair. Now clamp the sides of the blanket to the knee rail on either side (next to the control console and next to the gate). The sides of the chair provide a wind block. Before lowering the basket, be sure to remove the blanket so that you have an unobstructed view below you.

Very often, as the machinery and hydraulic lines cool, the arm settles. It can suddenly droop a few inches. This happens on all machines and, while it can be startling, it is not a cause for alarm.

If you need to mark the placement of the basket so you can return to that position (to take a meal break for example), make a plum bob by attaching a weight (a crescent wrench works well) to the tag line. Lower the line until the crescent wrench just barely touches the ground below. Tie off the tag line at that length and have your spotter mark the position of the plum bob on the ground with chalk. If you have to mark several positions, you can tab the line with tape instead of tying it off; label the tabs.

PAPERWORK

Paperwork is a crucial tool for the rigging gaffer and best boy. Paperwork helps you keep organized. It helps present your plans in a clear and professional manner. This is critical when negotiating labor and equipment with the production manager, so they can clearly see where and why you need the manpower and equipment you are requesting. Paperwork provides a paper trail, which helps reconstruct events that have been jettisoned from your memory banks, and makes it easy to remain accountable if the rental house or the accounting department should somehow make an error, or misfile an expense. Some of the paperwork that comes in handy for planning a rig are Rigging Schedule, Daily Hot Sheet, Special Equipment Schedule, Equipment Lists, and Expendable Lists.

A Rigging Schedule breaks down the manpower by date, and set (or location). It lists a description of the work to be performed, and the number of crew you estimate are needed to complete the work (e.g., 1 rigging gaffer, 1 rigging best boy, 4 riggers). The schedule provides additional columns where the actual numbers of electricians hired can be filled in each day. Keeping an ongoing log of labor makes it possible to shuffle man-days around without giving anyone the false perception that you are adding unauthorized labor. It is quite possible you can save a man 1 day and use him another day. Presenting the rigging schedule in a format like this makes it easy for the UPM to see how and why you have allocated the work, and helps you get the number of electricians you need.

A Special Equipment Schedule presents in a clear way when extra equipment is required: stake beds trucks, scissor lift, aerial lifts, ATVs, and so on. It may also be helpful to make a note when the special equipment requires extra electricians, such as an aerial lift operator.

A Daily Hot Sheet is made for each day of work, and is filled out on that day. It includes who worked on the crew that day, their in-time, lunch break, and out-time. This makes filling out the time cards a cinch and creates a paper trail for actual labor.

Of course there are lots of Equipment Lists, which many rigging gaffers maintain with a simple Excel spreadsheet. Ninety percent of inventory problems come from the best boy or the rental house not keeping careful enough track of equipment as it is added and returned during filming. You need a form to track it. Each time equipment is received or returned this form is updated, the transaction is noted, the date and time is added and the form is printed out and placed in chronological order in a the binder. The form automatically gives you a running total of the number of each item you have left on hand after each transaction.

Rigging gaffers typically keep everything organized on computer and in big binders. Depending on the show, you might need to make a binder for each stage or rig. Retain all receipts, memos, emails, or other correspondence with vendors, the production office, other departments, and the union local for future reference.

CHAPTER

Power sources

16

The power we need to run our lights can come from a number of sources: a small battery pack, a small 5500 W generator, via the power utility (a transformer connected to the power lines), a large diesel-powered portable generator, or a 480 V step-down transformer. In each case, the lighting technician needs to know how the system operates, its potential, its limits, and problems to watch out for. We'll start small and work our way up.

BATTERIES AND INVERTERS

In situations in which no other power source is practical—such as when shooting in a moving car, a boat, a remote cave, or on the run—a rechargeable battery pack can provide enough DC power to run a small light. Previous chapters described various tungsten, fluorescent, and LED lights and small HMI ballasts made to run on battery power. Lights as large as 1200 W HMIs can be effectively run on battery power; however, this requires some special equipment.

The key to a successful remote system is the battery. The design of batteries has improved greatly over the years. Nickel cadmium (Ni-Cad) batteries, nickel-metal hydride batteries (NiMH), and lithium-ion (Li-ion) batteries are commonly used for portable lighting fixtures, packaged as a block battery, or arranged in a battery belt (Figure 16.1). Each of these battery chemistries have their strengths, but the most recent of these, lithium-ion batteries, perform quite a bit better than their predecessors in important ways. Notably, Li-ion batteries do not display voltage depression, also called "memory effect," as Ni-Cad and NiMH batteries do.

Belt and block batteries are typically 12, 24, or 30 V. Small LEDs, dedos, and car kits are mostly 12 V; some use 24 V bulbs. Many commonly used lamp types are available in a 12 V or 24 V version (e.g., 12 V MR16). HMIs like the Pocket Pars, Joker-Bug, and Cinespace require 30 V batteries. The ARRI AC/DC EB 575/1200 ballast can run off 24 V DC to power a 575 W HMI, or 48-60 V DC to power a 1200 W head. Veteran gaffer Dwight Campbell uses the ballast with two 30 V, 24 amp-hour (Ah) lithium-ion LibertyPak battery packs (LB 800 5C) wired together in series, and reports that a 575 can run for around 1.5 hours, and a 1200 for 1 hour. Using these batteries, he has also used 200 W HMIs for 2.5 hours on a single charge.

Battery chemistry and care

Table 16.1 was prepared from data collected by BatteryUniversity.com and actual field-testing. It gives a good idea of the advantages and disadvantages inherent in the various battery chemistries.

Set Lighting Technician's Handbook, 4e. DOI: 10.1016/B978-0-240-81075-1.00016-7

FIGURE 16.1

Battery belts can be worn by the user to power either a light or camera.

(Courtesy LibertyPak.)

Table 16.1 Performance characteristics of various battery chemistries

Description	Ni-Cad	NiMH	Lead-Acid	Li-Ion
Memory problems	Yes	Yes	Yes	None
Low maintenance	No	No	No	Yes—none
Holds its charge	No (−20%)	No (−50%)	Yes (−5%)	Yes (−1%)
High temperatures	Good	Good	Fair	Good
Cold weather performance	Good	Good	Poor	Best (−20 °C)
Low internal resistance	Yes	Yes	No	Yes
High sustained voltage	Yes	No	No	Yes
Fast charge	Yes	No	No	Yes
Terminal voltage per cell (V)	1.2	1.2	2	4.2
Operational in any position	Yes	Yes	Not always	Yes
Cycle life expectancy	Up to 1000	Up to 500	Up to 300	Over 500
Weight per 100 Wh (lbs)	5	5	6	1.2
Environmentally safe	No	Somewhat	No	Yes

Lithium-ion

Li-ion batteries advantages include more power, less weight, faster charging speed, no memory, and good cold-weather performance. In contrast to NiCad batteries which require many hours to charge, some Li-ion batteries can charge in 30 minutes, and some designs can charge in as little as 15. Newer formulations of Li-ion technology are constantly being tested. We will not know the results of these experiments for a few years, but Li-ion technology shows great promise for further increases in

performance in the future. The downside to Li-ion technology is that Li-ion batteries age faster than other batteries; the total number of years in service is likely to be around two or three. This is particularly true if the battery is frequently used at a high current draw, such as with tungsten and HMI lights. Especially if you own the batteries, you might consider using two packs connected in parallel when powering high-current loads, when possible, to reduce current and increase capacity. This improves battery longevity.

The two factors that most effect aging are temperature and state of charge. Li-ions age more quickly if kept at a high temperature for long periods (like when a laptop computer is used connected to mains power for long periods of time, or when a battery is left on the charger after it is fully charged). They will also last longer if stored with only a partial charge.

Another potential downside to Li-ion batteries is that if subjected to certain kinds of abuses, they can catch fire. Preventing this kind accident requires that the cells are equipped with a variety of safety provisions that disable the battery under conditions that could lead to failure. Once disabled the battery cannot be repaired and must be discarded. Li-ion batteries may not be taken on airplanes unless they are IATA (International Air Transport Association)—compliant and certified by the Department of Transportation as "safe to fly." Certain manufacturers, such as LibertyPak, certify all of their products.

Achieving maximum performance from Li-ion batteries requires different operational techniques than those of Ni-Cad and NiMH batteries. Batteryuniversity.com offers a wealth of good, up-to-date information on the subject of batteries. They offer the following guidelines for operating Li-ion batteries:

Lithium-ion operation

- Avoid frequent *full* discharges because this puts additional strain on the battery. Several partial discharges with frequent recharges are better for lithium-ion than one deep one. Recharging a partially charged lithium-ion does not cause harm because there is no memory. (In this respect, lithium-ion differs from nickel-based batteries.) Short battery life in a laptop is mainly cause by heat rather than charge/discharge patterns.
- Keep the lithium-ion battery cool. Avoid a hot car. Don't leave them on the charger.
- For prolonged storage, keep the battery at a 40% charge level. When they are not going to be used for a while, do not recharge them fully.
- Avoid purchasing spare lithium-ion batteries for later use. Observe manufacturing dates. Do not buy old stock, even if sold at clearance prices.
- If you have a spare lithium-ion battery, use one to the fullest and keep the other cool by placing it in the refrigerator. Do not freeze the battery.[1]

Ni-Cad and NiMH

Although other performance characteristics are not as good as Li-ion, Ni-Cad batteries can be expected to operate well for twice as many cycles as other chemistries. Performance under controlled conditions shows that Ni-Cad actually has very little reduction in performance over 2000 cycles,

[1]Buchmann, Isidor. *Memory: Myth or Fact?* Batteryuniveristy.com. Copyright 2003–2005 Isidor Buchmann. Used by permission.

unlike other types. This may come as a surprise to readers who have experience with rented Ni-Cad battery packs, because we commonly run across Ni-Cad packs with degraded performance. The difficulty is that Ni-Cad are particularly susceptible to "memory" problems. Battery memory is reduction in the full charge voltage of a battery, which reduces the amount of time a battery can power a device with each charge cycle. A battery develops the problem if it is repeatedly recharged before having completed a full discharge, and also when the battery is left on the charger for days after being recharged. In normal use, we do not allow the battery to discharge fully, so memory is inevitable unless the battery is periodically "exercised." Exercise is simply discharging the battery fully—down to 1 V/cell. It has been shown that exercising a Ni-Cad battery once a month avoids the problem of memory. It is not necessary—in fact, it is counterproductive—to exercise a Ni-Cad battery any more than once a month. It is also not necessary to go to any trouble to discharge the battery fully every cycle if the battery is given its once a month exercise. Exercise is best performed with a battery conditioner, a specialized battery charger, which automatically brings the state of charge down to a full discharge without harming the battery by over doing it.

When NiMH batteries first came out it was thought that they did not have memory; it has subsequently become clear that they do, but not to the same extent as Ni-Cads. No scientific research is available on the result of exercising NiMH, but experts estimate that exercising them once every 3 months will prevent the kind of crystalline buildup that causes the "memory" issue.

If the battery is left for a long time in a memory condition, the crystalline formations are much harder to break down. However, the battery can usually be completely restored using a combination of exercise and reconditioning. Reconditioning is regular exercise down to 1 V/cell followed by a very careful slow deep discharge to 0.6-0.4 V/cell. If a Ni-Cad sits unused and unexercised for 3 months or more, it will require reconditioning. If the rental facility owns a battery analyzer, they can exercise and, if necessary, recondition all of your batteries before the prep. This will restore full performance in 9 out of 10 batteries that show degraded performance, and will weed out the ones that are beyond repair.

NiMH batteries will suffer damage if overcharged or overdischarged, or overheated, so special NiMH chargers must be used. NiMH batteries must be "topped off" (recharged) a short time before they are used because they have a tendency to lose charge. This is also true of Ni-Cad batteries, but they are not as prone to losing charge as NiMH batteries. It is often impossible to know the age of batteries when a rental house provides them. When you are relying on battery power for a shot, it is important to order more batteries than you need. It is safe to assume that some (if not all) will not be able to give a full charge.

Ni-Cad and NiMH operation

- Exercise the battery with a full discharge at least once a month for Ni-Cad; at least once every 3 months for NiMH.
- It is not necessary to discharge the battery before each recharge. This actually just puts more stress on the battery.
- Operation at high temperatures drastically reduces life cycle (reduced 20% at 86 °F, 40% at 104 °F). For better endurance, keep the battery out of direct sun.
- Avoid high temperature during charging. Charger should switch to trickle charge to cool the battery. Discontinue use of chargers that cook batteries.
- If not used immediately, remove the battery from the charger and apply a topping charge before use. Do not leave nickel-based battery on the charger for prolonged periods, even if on a trickle charge.

- Nickel-based batteries prefer fast-charging. Lingering slow charges cause crystalline formation (memory).
- A NiMH battery charger can be used to charge Ni-Cad, but not the other way around. A Ni-Cad charger will overcharge and permanently damage a NiMH battery.
- Batteries age more quickly and can be damaged as a result of exposure to heat.
- For prolonged storage, store the battery at 40% charge level. And keep it cool. Lead acid batteries are the only type that should be stored at 100% charge.[2]

Inverter systems

AC power supplies for fluorescents and HMIs can be powered using an *inverter*, a small electronic device that converts DC to AC. A battery-pack/inverter combination such as the Little Genny (Figure 16.2) provides 117 V, pure sine wave at 60 Hz.

When weighing different options to solve a particular power problem, it is worth bearing in mind that the process of converting battery power to 120 V AC comes with a high cost in efficiency. To maximize the potential of the batteries, it is better to power the load directly if possible.

FIGURE 16.2

The Little Genny Inverter System can power a Nila head for 5 hours, or a Kino Flo Diva or Bar Fly for 1 hour and 15 minutes. The Little Genny also works as an uninterruptible power source (UPS); you can unplug the charger power supply and plug it into a different outlet without losing power to the light. It can be charged using a 24 V power supply or a special fold-up solar panel. The power is clean and can be used to power a laptop computer or charge a cell phone. It can also provide 24 V directly from the battery.

(Courtesy LibertyPak.)

[2]Taken from various articles by Isidoe Buchmann on Batteryuniversity.com. Used by permission.

FIGURE 16.3

This inverter system has a charger, 1800 W inverter, and 184 A/hour battery pack. The inverter creates 120 V AC 60 Hz (or 230 V on European model) from 12 V DC input (the battery). Each battery pack can power four four-bank, 4-ft. fixtures for up to 56 minutes from a full charge.

(Courtesy of Kino Flo, Inc., Sun Valley, CA.)

As mentioned earlier, many small lights (even fluorescent and HMI ballasts and many types of tungsten lamps) are available in 12, 24, or 30 V versions.

Kino-Flo no longer manufactures their battery pack/inverter system, but they are available in the rental market. The system employs a 194 Ah, sealed, nonspillable, lead-acid battery, battery charger, and 1800 W inverter (Figure 16.3). The entire system is small enough to fit in the trunk of a car. The inverter supplies 120 V AC with a true sine wave. In order to preserve battery life for actual filming, the system provides AC feedthrough to power the system off "shore power" during prelighting, then switches instantaneously to battery power when disconnected from AC. No restrike is necessary. The inverter works with 10-16 V DC input and weighs 40 lbs. The charger can recharge the battery to 75% power in about 2 hours and weighs 21 lbs. The battery with casters weighs 188 lbs.

120 V DC lead-acid battery packs

If you are really desperate, you can always make 120 V the old-fashioned way – by connecting ten 12 V wet cell (lead-acid) batteries in series, you get 120 V DC. Commercially available battery packs are specially made with nonspill caps on the cells, typically housing five 12 V cells to a case. Each case weighs about 130 lbs. Batteries are made in various capacities, ranging up to 100 Ah and more; however, a 45 Ah rating is typical. As an example, when fully charged and operated continuously at 80 °F, the Molepower battery pack, manufactured by Mole-Richardson, provides power as follows:

4000 W for 20 minutes
3000 W for 40 minutes
2000 W for 1 hour
1000 W for 2 hours and 40 minutes

As you can see, a battery's capacity is affected by its rate of discharge: the lower the rate, the greater the total power output. At lower temperatures, wet cell batteries have reduced capacity; the times noted should be reduced by 7% for each 10 °F below 80 °F. Additionally, if the battery is not run continuously, its total running time is greater than the times noted. Finally, the performance of wet cells decreases with age. In a given battery pack, there will likely be a mix of newer and older cells, making it hard to predict the battery's performance precisely.

It takes 6–8 hours to charge a wet cell battery pack properly. A trickle charger is often used (input: 120 V AC, 15 A, 60 Hz; output: 120 V DC, 12 A). It is not a safe practice to use spillable lead acid batteries on set. Spilled sulfuric acid causes serious damage to the equipment and people it contacts.

GENERATORS

It is a convenient property of electrons that they can be induced to move through a conductor by passing the conductor through a magnetic field. An *alternator* creates electricity using this principle. A rotor (the rotating part of the alternator) turns inside a stator (the stationary part of the alternator). When the magnetic field of the rotor passes through the stator coils, current is induced in the coils. The coils pass first through the positive pole of the electromagnet and current flows in one direction. The coils then pass through the negative pole and the current flows in the opposite direction. If the positive and negative poles and the speed that the rotor turns are arranged so that current reverses direction 120 times/second, the result is a sinusoidal AC 60 Hz waveform (as was illustrated in Figure 12.16). Changing the field strength of the magnetic field varies the voltage of the electricity flowing in the coils.

It takes a significant amount of force to turn the rotor. In a generator, this is provided by the *prime mover*—a motor. Therefore a generator consists of two parts: a motor, which burns fuel to create mechanical force, and an alternator, which converts that mechanical force into AC current. When the load is increased, the magnetic resistive force of the coils increases. This in turn increases the strain on the shaft, causing the engine to want to slow. The controller regulates the speed of the motor. The instant it senses the motor slowing it sends a signal to the actuator to increase fuel flow—just as when a car starts to climb a hill, you have to put your foot down on the gas to maintain the same speed.

PUTT-PUTTS (PORTABLE HONDA GENERATORS)

For small amounts of remote power (up to about 5500 W), a portable Honda-style "putt-putt" generator is a very handy unit to carry on any show. In rough terrain, it enables lighting in places that a heavy diesel plant cannot reach. At night, a putt-putt can save running hundreds of feet of cable to power one 2500 par to light the deep background. A Honda can power work lights during wrap, allowing the main plant to be shut down and the cable wrapped. One Hollywood insert company (which shoots a lot of MOS establishing shots for movies and television shows) lights all its night exteriors quite nicely with little more than three putt-putts and a dozen PAR 64s. The generators discussed in this section run on gasoline, have a fuel capacity around 4.5 gallons, and will run for at least 4½ hours on a tank of gas (about a gallon per hour at full rated load).

There are two types of portable generators commonly used in film lighting: the older generation, commonly called AVR (because they employ an automatic voltage regulator), and the newer models, which employ a solid-state inverter.

AVR generators

Until relatively recently, small generators required significant modification to be reliable and useful for lighting on a film set. Typically, a generator such as the Honda 5500EX (shown on the right in Figure 16.4) would have the circuitry completely reworked with a split solenoid (allowing 50 A, 120 V, or 120/240 V AC); in addition, it would be fitted with a precision speed control, beefier regulator, better battery charging system, a fuel pump to reduce fuel flow problems common with gravity feed systems, and a fuel solenoid to automatically shut off fuel on shutdown to eliminate dribbling and flooding. In addition, the factory generator is typically mounted on four large pneumatic tires and encased in a protective metal roll-cage. This type of generator has proved an adequate source of power for all kinds of lights, including HMIs and fluorescents.

With this type of generator, the AC frequency is tied directly to the generator's motor speed, and with such a small engine, the governor can be touchy and easily upset by variations in the load or fuel flow. The resulting variations in the hertz rate can cause HMI "flicker" When using magnetic ballasts. It is a wise precaution to monitor the hertz rate with an inline meter, or use flicker-free ballasts when powering HMIs from a putt-putt to allow greater tolerance for variation in hertz rate. The governor tends to be less stable when the load is very small. To increase stability, it helps to put a bit of a resistive load on the generator. Adding a tungsten light to the generator before striking an HMI dampens the hit, and helps the generator pick up the load. With no load on the generator, when the HMI is struck, the generator voltage dips, and this can set up an unstable oscillation, with the ballast trying to draw more current. This usually causes the ballast to shut down. A small

FIGURE 16.4

(Left) Honda EU6500, (Right) Honda 5500EX.

(Reproduced by permission of Guy Holt, ScreenLight and Grip/HD plug and play packages, Boston.)

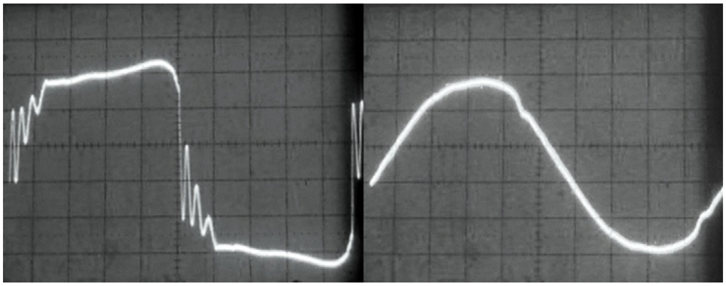

FIGURE 16.5

These two waveforms illustrate the effect of a nonlinear load on two different small portable generators. The load was two 1200 W HMIs, and a Kino Flo Wall-O-Lite; none of them power factor corrected. The waveform of the AVR generator (Honda 5500EX) on the left has a flattened peak, and jagged rise and fall. The waveform on the right is a (Honda EU6500) inverter-type generator. It shows very little waveform distortion.

(Reproduced by permission of Guy Holt, ScreenLight and Grip/HD plug and play packages, Boston.)

incandescent load on the generator—even as little as 300 W—will stabilize the voltage when the HMI strikes. With this type of generator, it is a bad idea to change the load during the shot with flicker devices or sudden light cues.

A small AVR-type generator is susceptible to noise created by nonlinear loads. Figure 16.5 shows this waveform distortion on a scope. This waveform distortion can make it hard for other loads operating on the same circuit to operate properly. In fact, it has been pointed out that battery chargers, which draw current at the peak of the waveform, will not function at all when the peak of the waveform is flattened as shown here, and are likely to heat up and burn out. Clearly PFC ballasts would make a big difference here. Not only would they allow cleaner power for all fixtures and devices connected to the generator, but they would also allow more lights to be connected to the generator, because they use the power more efficiently. This is an important advantage when the power source is small to begin with.

Modified windings

One limitation of small generators (as they are delivered from the factory) is the total amount of current that may be pulled by one 120 V light. To use all 45 A available, on one 120 V circuit, a special retrofit must be made to the alternator, arranging the electrical windings in parallel instead of in series, as shown in Figure 16.6. From the factory, the alternator has two windings, wired in series, which provides two 20 A, 120 V circuits or one 20 A, 240 V circuit. In this configuration, you cannot pull more than 20 A per side, and the generator runs best if you keep the two circuits evenly loaded. In this configuration, for example, you could not run a 5k or 4k par HMI. (But you could run these lights using a European 240 V 5k lamp or 240 V 4k ballast.) Generator suppliers of motion picture generators sometimes split the windings so that you can switch between parallel windings (one 45 A, 120 V circuit) or series (two 20 A, 120 V, or one 20 A, 240 V circuit). You will also encounter generators that are hardwired with the windings in parallel, with no 240 V outlets, that you can run to full capacity on one 120 V 45 A circuit.

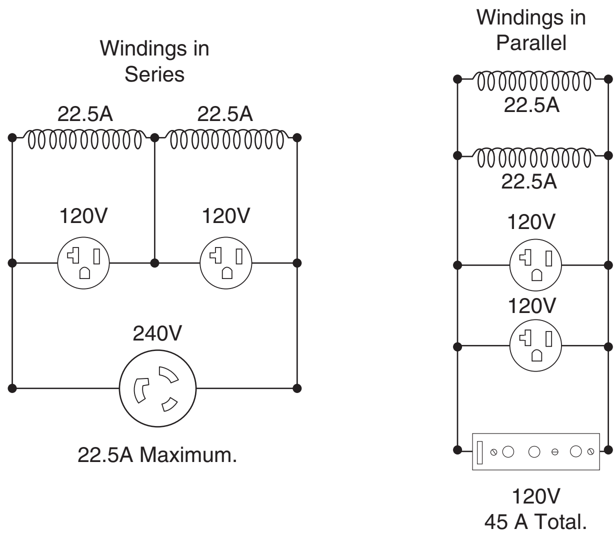

FIGURE 16.6

The current available from the windings is doubled when they are wired in parallel. A retrofit involves resizing all the electrical conductors to handle the higher current.

240-120 V transformer

Another way to solve this problem is using a 240 to 120 V step-down transformer, as shown in Figure 16.7. The transformer draws 240 V, allowing the generator to have perfectly balanced current on both windings. The transformer provides all 5500 W output from a single 120 V circuit (45 A). Not only does this allow you to power a 120 V 5k, it also allows you to more fully use the capacity of the generator. You can never run into the problem of overamping one circuit while there is still capacity available. The transformer also dampens noise from nonlinear loads to the generator.

Honda EU inverter generators

In 2007, Honda introduced their line of quiet-running inverter generators—the EU series. The EU6500is is popular for use as a lighting generator, with about 5500 W of power and a weight of about 253 lbs with no fuel. Another portable solution that is being used effectively for lighting is to run two smaller EU3000is generators in parallel—for a total capacity of 5600 W. Each one weighs about 134 lbs. The EU i-series generators use an electronic inverter that generates a clean sine wave not dependent on engine speed (by use of pulse width modulation of IGBTs operating at high speeds—the same way that sinewave dimmers create an ideal sine wave; see Chapter 13). The high-quality sine wave can reliably power any device, including sensitive electronics such as computers and video systems. This system is much better equipped to deal with current harmonics from nonlinear loads than AVR generators (Figure 16.5). At the same time, this generator integrates the alternator into the flywheel, decreasing the size and weight of the generator significantly, as shown in Figure 16.4.

FIGURE 16.7

240-120 step-down transformer with EU6500 generator.

(Reproduced by permission of Guy Holt, ScreenLight and Grip/HD plug and play packages, Boston.)

The Honda EU6500is can be started from a recoil starter (pull start) in the event that the battery is flat, but it is normally started from the start switch, which is fully automatic. This generator can also be controlled remotely. To save fuel and reduce noise, a feature called the Eco-throttle automatically reduces motor speed when the load is reduced. This is a huge fuel saver (running at ¼ power, the generator can run for 14 hours on a tank of fuel); however, when you are adding substantial loads to the generator, you want to have it running at full speed, so turn the Eco-throttle feature off before adding them. A system ground terminal is provided on the lower right side of the generator for grounding and bonding the non-current-carrying metal parts of the generator to a grounding electrode or bonding to other power sources.

The EU6500is has a number of helpful displays. Three lights show you: (1) that the output circuits are energized (green), (2) if there is an overload, or inverter overheat (red), and (3) if the generator has sufficient oil (red). The generator automatically shuts down if the oil starts approaching a level that would cause engine damage. The unit also has a LCD display that can cycle through four different pieces of useful information by pressing its MODE button. These are: (1) maintenance hours, (2) a rough indication of power currently being used (shown in VA), (3) engine RPM, and (4) battery voltage. In the event that the generator must shut down, the display will also tell you the reason—OIL, for example.

The fuel gauge is a mechanical type located on the top of the unit, next to the fuel filler cap. The battery is located behind a cover below the main controls and receptacles. The oil filler and pull start are inside the right side access door. The air filter is inside the left side access door.

Before operation:

- Be sure the generator is located at least 3 ft. from building walls, and placed on level ground, and do not leave the gas can or any other flammable materials close to it.
- Check fuel supply and oil level.

- Double check that the exhaust will ventilate freely, and that it is not blowing into a confined space.
- Set the output voltage (120 V only or 120/240) before turning the generator on.
- Disconnect all loads for startup.
- Open the fuel valve, and set the Eco-throttle to OFF (until the unit is warmed up).
- Start the unit by simply turning the start switch as you would a car.

The factory setup for the receptacles provides two separate 20 A breakers for the two Edison outlets (red and blue), a 30 A breaker for the L5-30 twist lock 120 V (red), and a 30 A breaker for each pole of the L14-30 240/120 V receptacle (red and blue). The maximum continuous load should not exceed 5500 VA (but according to the manual, may be as high as 6500 VA for 30 minutes or less). To keep the loads balanced when powering loads from various receptacles, you need to be aware of which receptacles are red leg and which are blue. Total load should not exceed 45.8 A.

Troubleshooting putt-putts

Hiccups in the power line are commonly caused by inconstant fuel flow. The generator must be on level ground. The fuel tank is mounted only slightly above the carburetor; if the putt-putt is on a slope, with the fuel tank on the low side, fuel can get too low to flow properly, which disrupts the power. When powering lights on a moving vehicle or vessel, rocking or jerking can interrupt fuel flow, which causes hiccups in the power line. Keeping the tank topped off can help this, but the best solution is to use a unit that has a fuel pump.

A common area of breakdown on the Honda AVR-type generators is the circuit that recharges the battery. If the circuit fails, the battery goes flat; as it does, the governor has difficulty maintaining consistent RPM. First the hertz rate becomes unstable, starts oscillating, and then slowly drifts lower and lower. If this happens, you can fix the problem temporarily (and get the shot) by jumping the battery with a car battery.

The performance of a small engine is greatly affected by air density. One can expect to lose engine performance with altitude—about 3.5% per 1000 ft. (above 3000 ft.). In addition, at high elevations the mixture must be leaned out or the fuel/air mixture will be too rich, causing the engine to run rough, burn too much fuel and foul the spark plugs. The carburetor can be adjusted to make a lean fuel/air mixture to avoid this problem. If the carburetor is adjusted for a lean mixture it must be changed back before using the generator again at lower elevations. Otherwise, the fuel/air mixture will be overly lean when used nearer sea level, and this can cause very high cylinder temperatures and seriously damage the engine.

FULL-SIZE GENERATORS

Most generators used today are relatively simple to operate, fully automated, and self-diagnostic (Figure 16.8). Movie generators are baffled to minimize noise for sound recording. They are very precisely electronically governed at 60 + 0.2 Hz to be reliable when used with HMI lights and are equipped with a hertz readout and hertz adjustment on the main control panel. Similarly, voltage is precisely maintained electronically and can be adjusted. Dual plants of 90-168 kW are commonly

FIGURE 16.8

(A) Tractor-mounted twin 168kVA generators. (B) Two axle, 168kVA tow plant. The vents on the top open automatically when the engine is turned on. The side doors provide access to the engine. (C) On the back of the unit, the bottom doors cover the buss power distribution outlets and above that is the digital control panel.

(Courtesy Illumination Dynamics, San Fernando, CA. An ARRI Group Company.)

mounted on the tractor of the production van. Trailer-mounted two axle “tow plants” are also common, ranging from small 24 up to 360 kW. Almost all power plants use diesel engines. The emissions requirements for gasoline engines are more complicated to achieve; as a result gasoline powered generators have become rare.

Generators are rated in kilowatts. However, in the film business (and only in the film business), we commonly refer to generators as rated in amps. We will refer to a 108 kW plant as a 900 A plant—which is the total amperage capacity *at 120 V*. Real-world electricians (and electrical inspectors) refer to the generator as 108 kW, and the service as “300 A three-phase at 120 V”. They would never call it a 900 A generator. In fact, if you said you had a 900 A plant, to them this would mean you had 900 A *per phase*. Table 16.2 shows some common sizes for generators and how they translate.

Generators provide Cam-Lok connection for the feeders. Some also provide copper buss bars for the connection of lug feeder cable.

Two axle “tow plant” generators typically have a fuel capacity of 80-150 gallons. A 140 gallon tank typically can provide something like 117 gallons of usable fuel. Because the fuel tank is long, wide and flat the tank can have large quantities of unusable fuel—below the level of the fuel pick-up. A 60 kW (500 A) diesel generator under full load burns fuel at a rate of about 4.8 gallons/hour. A modern 144 kW (1200 A) plant burns 13.6 gallons/hour at full load, 6.9 at half load. A 500 A gasoline generator consumes about 6 gallons/hour at any load.

Generator manufacturers try to make their plants as bulletproof as possible. It is worth finding out what kinds of protections your particular generator provides. Some generators automatically shut

Table 16.2 Common generator sizes: kW versus amperage, and total capacity versus working load

What we call it	What everybody else calls it	Maximum capacity per phase	Plan on using
Total Amperage Capacity (at 120 V) (A)	*Rating (kW)*	*Amps Per Phase at 120 V Three-Phase (A)*	*Continuous Working Load (80% of Total Capacity) Amps Per Phase at 120 V Three-Phase*
200	24	66	52
350	42	118	
450	50.4	150	120
500	60	166	132
750	90	250	200
900	108	300	240
1000	120	333	266
1200	144	400	320
1400	168	466	372
1500	180	500	400
1800	216	600	480
2400	288	800	640
2500	300	833	666
3000	360	1000	800

Shaded rows indicate most common sizes for modern power plants.

down when they are about to run out of fuel. There is significant downtime when a diesel motor has run out of fuel, because you have to bleed the fuel lines to get the air out. Not all generators are equipped with this feature. Similarly, generator suppliers often incorporate redundancy of parts so that if something fails in the field, the generator can be brought back online quickly. For example, a generator may have dual voltage regulators, dual electronic governor controllers, and dual fuel pumps to provide redundancy in case a part fails.

Electrical configurations

A generator may produce different voltages and different configurations of power, but inside the alternator is three-phase—three sets of coils, arranged 120° out of phase from one another, creating three-phase AC current. To allow for a variety of different uses, each of the three alternator coils (marked L1, L2, and L3) are tapped in four places, creating 12 taps (marked 1-12). From this, many configurations are possible (see Figures 16.9 and 16.10).

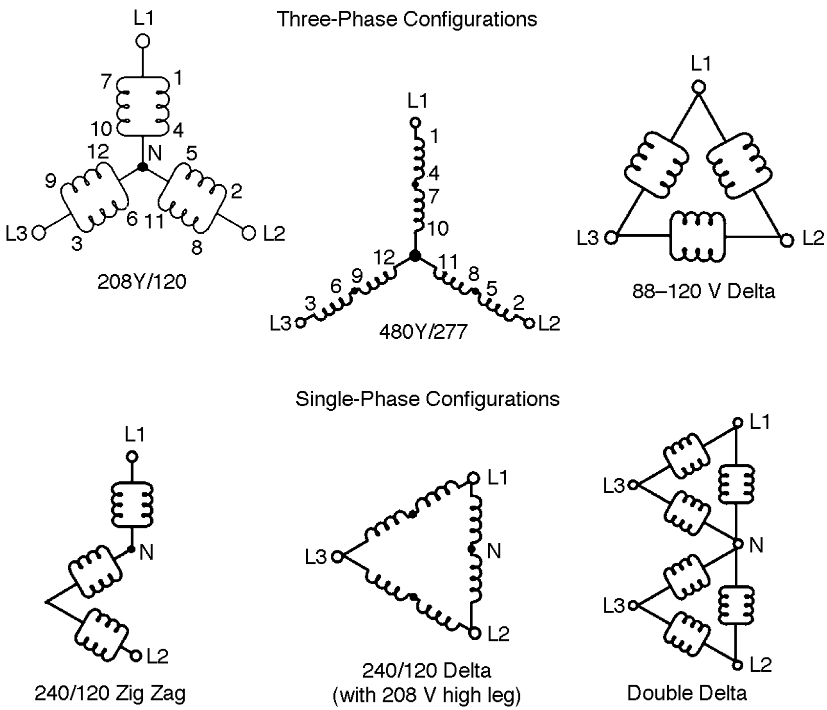

FIGURE 16.9

Alternator coils are tapped in 12 places to allow versatility in possible electrical configurations. A multipole, heavy-duty, rotary switch configures the coils. 208Y/120 three-phase is the standard configuration. The zigzag configuration and double delta configuration can both be used to create 240/120 single phase from all six coils (tapped at L1, N, L2). On the zig-zag configuration the gap between N and L2 is the "open leg" of a delta, giving 120 V. Note that in each configuration, all six coils are tapped as evenly as possible.

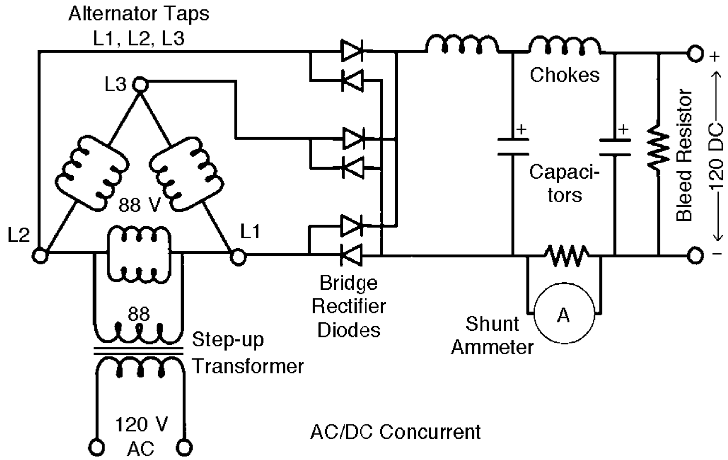

FIGURE 16.10

AC and DC derived concurrently from an 88 V delta three-phase AC configuration. A step-up transformer creates 120 V AC by tapping between L1 and L2 (a second transformer between L2 and L3 could also be used to create 120/240 AC). The three 88 V AC legs are converted to 120 V DC using rectifier diodes, chokes, and capacitors.

A large selection switch located inside one of the rear doors allows the user to choose the configuration. The switch arranges the configuration of the 12 taps to provide the desired type of service. *Before* the engine is started, the switch position must be selected (all circuits totally dead). Damage to this very expensive switch can result if the switch position is changed with the engine running, including while at idle. Typical selections are:

Single-phase 240/120—Two phase wires (red and blue) and neutral, plus ground. The benefits of using a single-phase system are discussed in Chapter 15. When configured this way, the capacity of the generator is reduced, generally by about a third.

Three-phase 208Y/120—Three phase wires (red, blue, and black) and neutral, plus ground.

Three-phase 480Y/277—Three phase wires at 480 V (brown, orange, and yellow) and neutral, plus ground. Used for powering 480-208 V step-down transformers, or 480 V three-phase loads such as the Softsun, or a large air conditioner.

AC/DC Concurrent—Some plants also provide two-wire DC and AC concurrently (DC is created by rectifying a portion of the AC power).

Each time you change configurations, the voltage adjustment will have to be recalibrated. Do not connect loads without recalibrating the voltage. To remind yourself and others, each time the voltage is changed, the new voltage/configuration is written prominently on a piece of tape and attached where it will be clearly seen at the panel of the generator.

Large-scale live broadcast events, like the Academy Awards (Oscars), the Emmys, the Grammys, and the Olympics have to have a failsafe power system. In order to provide complete redundancy, generator suppliers have devised ways to run one generator in complete sync with another generator

or with the utility power and run in parallel with it. This is called *paralleling* or *cogening*. The idea is that in the event that either one fails, due to utility power blackout or generator failure, the system will continue to operate without a single moment of interruption. More information about cogen systems is available on the *Set Lighting Technician's Handbook* Web site.

Control panel

Figure 16.11 shows the control panel of a typical modern generator. The OFF/START/RUN switch starts the generator at idle for warmup. The RUN position brings up to speed, ready to power the set. Displays show amperage for each phase, system voltage, and Hz rate. Adjustment to the voltage and Hz rate are provided on the panel. As we said earlier, anytime the configuration of the alternator coils is changed, the voltage will require adjustment. Typically, generator operators set the voltage slightly high (124 V) to help make up for inevitable line loss. Generator suppliers typically recommend the voltage not be adjusted more than 5% over line voltage, as this can lead to trouble with voltage regulation. The ammeters are handy for checking the balance of the load.

The panel also provides the engine instruments—water temp and oil pressure. These should be checked as regularly as any of the others. High water temperature indicates low oil, low oil pressure, and lack of proper airflow to cool the engine. In any case, a high temp reading should be addressed ASAP.

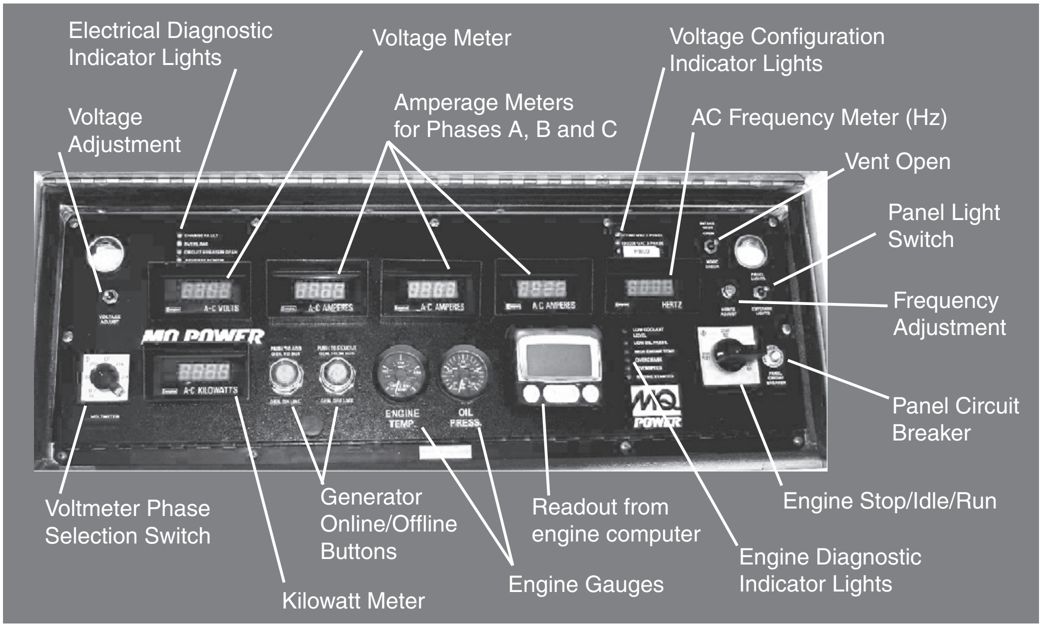

FIGURE 16.11

The digital control panel.

(Courtesy Illumination Dynamics, San Fernando, CA. An ARRI Group Company.)

Notably absent from the control panel are fuel gauges. As 90% of problems with generators are fuel-related, this is something you might expect to have on the panel. Typically, the operator lowers a dipstick into the fuel tank to check fuel quantity.

The circuit breakers or electronic overcurrent protection switches are usually located inside the alternator compartment near the selection switch, or on the main control panel. In most situations, this overcurrent protection may serve as the overcurrent protection for the feeder cables. However, these breakers are there primarily to protect the alternator in the event of an overload or short circuit. Depending on the size of the cables connected, the AHJ may require an external form of circuit protection, or a disconnect so that power may be disconnected in an emergency (such as a generator fire). A generator is permitted to use a single circuit breaker even though the maximum current will depend on the voltage selection. When 480 V power is used, the maximum current from the generator will be proportionally lower. For example, a 125 kW generator will have 400 A circuit breakers for normal use at 208/120 V, but it can safely provide is only 180 A when run at 480 V. In order to provide circuit protection at the appropriate amperage the circuit breakers are set up with circuitry that either diverts the electricity through a separate set of appropriately rated circuit breakers when the switch is positioned for 480 V power, or uses a shunt trip in combination with a solenoid inside the breaker to enable the existing circuit breakers to be switched automatically to provide circuit protection at the appropriate rating.

Further information on the operation of generators, and how to assess and troubleshoot problems is available on the *Set Lighting Technician's Handbook* Web site.

Generator placement

The sound department has a vested interest in where the generator is placed. Despite baffles that deaden engine noise, generators can be a nuisance for the sound department. Place the generator around the corner of a building or behind a big vehicle, a little distance from the set. Point the noisiest parts (the exhaust ports) away from the set. Electricians must sometimes run very long lengths of feeder cable to get the generator far enough from the set; once placed, it can be a lot of trouble to move it, so it is worth getting it well placed initially.

Noise and diesel exhaust should also be considered in relation to residences. Residents are liable to get irate if you park a generator in an echo chamber, like an alley between apartment buildings, especially when people have their windows open or are trying to sleep. Not only can the noise be unbearable, the exhaust is noxious.

The generator operator or transportation personnel must make sure that the plant is secured and stationary. The emergency brake must be engaged, if equipped, or chocks must be placed under the wheels to prevent movement (fire code regulations). It is a common misconception that the generator must be perfectly level or the engine will be damaged. This is not generally true. The main consideration is for the fuel in the fuel tank, but if the fuel intake is properly installed (in the *center*, *curbside*, at the *bottom* of the tank), being out of level does not adversely affect fuel intake. It is worth finding out from the supplier where the fuel intake is located. If conditions dictate that you must run the generator out of level, make sure the fuel filler and vents are high and the fuel pickup point is low.

Finally, the fire marshal will have several concerns related to generators. The generator must not be parked under anything that is likely to catch on fire, such as dry foliage. (Remember that the exhaust ports point up.) It must not block fire hydrants or exits. A multipurpose fire extinguisher

(20-BC) or equivalent must be available. It is a good idea where possible to take the fire extinguisher out of the engine compartment where it is stored. If the generator catches fire, it is not going to do much good in there, and the fire marshal will be glad to see it out. If the generator requires refueling, it must be shut down before refueling begins, and a “static line” attached between the fueler and the generator. There must be no smoking near the generator.

Selecting a generator

The size of generator selected for a job should be based on the power requirements of that job. Although one naturally might want a larger generator “just in case,” overkill can be bad for the plant. A generator should be run at 70-80% of its rated maximum load. Over time, running under very light loads causes all sorts of problems, including glazing the cylinders, which can destroy the engine. Nothing is better for a rough-running engine than to run it under substantial load for a couple hours. Generator rental companies use *load banks* (big resistance banks) for this very purpose as part of a regular maintenance schedule. You see a lot of soot and smoke in the exhaust at first, until the engine cleans itself out.

In some situations, you will have to oversize the generator. A large plant is better able to pick up large loads. If light cues will involve large load changes, the plant should be oversized. Lightning Strikes units require a larger generator. Large dimmer loads require the generator to be at least 1.5 times bigger that the nominal load.

Flexibility in load capacity is one advantage of having two tractor-mounted plants. In addition to having backup in case one plant fails, you have the ability to run a lot of power or very little as necessary. Tractors provide increased fuel capacity, up to 300 gallons, enough to keep a plant running for as long as 3 or 4 days.

The advantage of a tow plant is that it is generally quieter than a tractor-mounted plant; the large flat fuel tank effectively blocks sound so it does not reverberate out from under the plant as it does with a tractor-mounted plant. When filming a period Western in a peaceful, remote stretch of New Mexico, you can hear a car 3 miles away—never mind a 200 HP diesel engine 500 ft. up the mesa. You need a quiet plant or you’ll be running cable up hill and down dale.

480 V SYSTEMS

Increasingly, 480 V power is finding use in production. Figure 16.12 shows large 480 V Delta to 208/120 V wye transformers powering a large number of dimmer racks and HMIs. The 480 V service can originate from a service panel on location (from the power utility), or from a generator which is switchable to provide 480/277 V power. For set lighting, 480 V power is used for one of two purposes: it may also used to power 480 V equipment such as the Luminys 100k SoftSun, but most commonly, it is used to power a step-down transformer to provide 208/120 V power on set. A 480 V feeder run reduces line loss and the amount of cable required to overcome line loss significantly. When the power source is located a long distance from the shooting location, it may be advantageous to run 480 V feeders from the power supply to a location near the set, and then use a transformer to step down to serviceable voltages. Using 480 V feeders reduces the necessary cable by more than half. A 480 V Delta to 208Y/120 V transformer receives three-phase, 480 V plus ground, with no neutral conductor. With no neutral required, the total reduction in cable as much as 66% of what would be required with 208/120 V service.

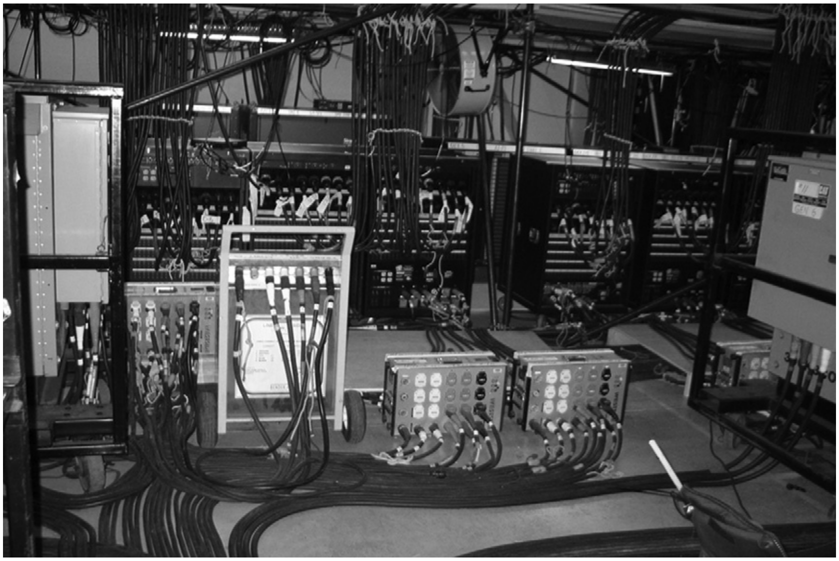

FIGURE 16.12

This rig has got it all. On the left and right side of the picture are seen two 480 V transformers. Spider boxes lead to a row of dimmer racks. Socapex cables exit the racks heading straight up into the rig. A Bender Class C GFCI unit (on wheels, left) provides leakage current protection for feeder cables that power distribution in wet areas. Notice that plywood bridges separate the cables where they cross over one another and provide plenty of ventilation space for the cables that pass under the bridge. Note also large powerful fans hanging over the dimmer racks to keep the air circulating.

(Courtesy Bender, Inc.)

Four hundred and eighty volt power is also commonly used for large air-conditioning units and is sometimes employed by the effects and stunts departments for their equipment, but these uses are not within the union jurisdiction of lighting technicians.

When 480 V power is used, the cable connectors and distribution equipment are color-coded as follows:

Brown—Phase
Orange—Phase
Yellow—Phase
White—Neutral (if used)
Green—Ground

You can remember the color-coding using the acronym BOY. Double-jacket type W Entertainment cable is used, and any spider boxes or other distribution equipment must be designed, tested, and listed for use with 480 V power, to insure proper buss bar spacing.

Installing a 480 V step-down transformer is not a small undertaking, and requires special equipment, knowledge, and *training*. This includes knowledge of the special distribution equipment,

color-coding and labeling procedures, special grounding procedures, knowledge of the necessary voltage drop calculations, voltage drop mitigation, sizing the power source and the transformer, special metering practices, and required personal protective equipment. It also requires special training in how to recognize and avoid hazards associated with higher voltage systems. Very serious potential hazards exist by mishandling 480 V service, including electrocution and arc blast. An arc blast is a plasma explosion caused by a 480 V arc, which engulfs everything within a 4–10-ft. radius in flame, extreme heat, toxic fumes, and a shower of molten copper as it destroys the service equipment. If being set on fire, burned by molten metal and asphyxiated is not bad enough, the clap from an arc blast is so loud it can to cause permanent hearing damage. Arc blasts from service in the range of 480 V is well known to electrical contractors as one of the most serious potential hazards of their trade. All this is to drive home the point that training and proper procedure is absolutely essential. Four hundred and eighty volt service is discussed further on the *Set Lighting Technician's Handbook* Web site.

UTILITY POWER

Studio facilities are designed with large quantities of electrical service to provide for lighting loads. When shooting on location, we typically bring our own generator to provide this service. However, in certain circumstances, you may want to consider other options for obtaining power: (1) have the power company make a line drop and install a kilowatt-hour meter at the location, (2) employ a qualified person to tie into the building's service at a panel board, or (3) use small amounts of power from house circuits.

Line drops from utility power

A line drop is sometimes less expensive than renting a generator. If shooting takes place in one location over several weeks and the building cannot supply sufficient power, you can have the power company make a line drop from the power utilities' pole-mounted transformers and install a kilowatt-hour meter at the location. A licensed C10 electrical contractor can then install a service panel with main breakers for the system from which the film's distribution system can draw power. Although a line drop involves some significant initial expense, the line drop has advantages over a tie-in, because it is a designated circuit with sufficient amperage; it has advantages over a generator, because it is silent and does not burn fuel. The utility may or may not be able to accommodate you, depending on what is available on the pole and how much power is required.

Tie-ins

A tie-in taps power directly from a building's existing service panel, drawing power from the building's permanent feeder cables. In locations such as a high-rise office building where it may be very difficult or impossible to run 4/0 cables up a 20-story building, a tie-in can save a great deal of labor and expense. The amount of power is limited to the excess capacity available from the existing system. If necessary, two tie-ins can sometimes be made allowing the power to tap two different building feeder circuits. Similarly, when filming in a warehouse, the building is likely to be supplied with an untapped industrial-size transformer. Depending on your power demand, this may or may not provide enough power, and may need to be supplemented.

The available capacity and voltage configuration should be metered by a properly qualified building engineer or a licensed electrical contractor—for this discussion, let's just call him Joe. The decision to make a tie-in involves many parties including Joe, the building rep, the gaffer, and the UPM to determine whether a tie-in is feasible and provides a useful solution. A permit must be obtained to perform the tie-in, and an electrical inspector will likely inspect the work. If power at the location is available at a higher voltage, Joe can install a step-down transformer to 208/120 V. In any case, Joe will terminate the tap cables to a main disconnect with appropriate overcurrent protection and appropriate connectors for the feeder cable (Cam-Lok).

Under no circumstances should a lighting technician open up an electrical panel, take meter readings from an open panel, or make a tie-in. It is illegal and potentially very dangerous to do so without appropriate training and qualifications. Joe has the appropriate meters, personal protection equipment, tools, experience, and knowledge.

Approach protection

To comply with the NEC, once the tie-in is complete, any exposed energized conductors (like those in an open service panel) must be guarded from approach and accidental contact.

The National Fire Protection Agency Part 70E (Standard for Electrical Safety in the Workplace) imposes specific requirements any time there are live exposed parts, such as an open panel, or exposed copper buss bars. It recommends a perimeter 10-ft. radius around any exposed, energized electrical equipment. This zone should be clearly labeled and taped off. Any nonqualified persons needing to pass through the 10-ft zone should be escorted. Additional safeguards include attaching rubber matting to the face of the panel, locking the door to the room, placing signs that say "Danger Live Cables" or "Danger High Voltage" at the doorway to the room and at the service panel.

Additionally, it is recommended that no conductive materials or electrical equipment be stored, carried or placed within 10 ft. of any exposed, energized parts of the distribution system, including exposed connectors on the distribution system. In addition, NFPA 70E specifies that any tie-in or disconnect must be barricaded in such a way as to prevent any unsuspecting person from approaching within a certain distance. The distance of this barricade must be in compliance with formulas laid out in NFPA 70E.

Using available outlets

Sometimes you simply don't have the option of using your own distribution system. You are forced to use the existing wall circuits at the location. If you plan on doing this extensively for a given location, it is a good idea to thoroughly check the existing service. When you use available power, the best boy electric should first find the breaker box and check the amperage of the circuits. They are usually 15 or 20 A. Count the number of separate circuits. Number the circuits and label the outlets with the circuit numbers. If you are not the only department that needs to use house power, you have to count on hair-curling irons or blow dryers also needing power. Run stingers from different sections of the house to have as many circuits as possible available.

The electrical code specifies that in new houses there must be two designated 20 A circuits around the counter of the kitchen. These circuits are handy, because they are not wired to any other outlets. Other designated circuits are those for the laundry. Wall outlets, including the fused 20 A bathroom outlet, usually share circuit breakers with other outlets and overhead fixtures.

CHAPTER

17 Special circumstances and practices

SHOOTING ON MOVING VEHICLES

The standard method of shooting a scene in a moving car is to put the car on a low-riding flatbed trailer—a *process trailer*—and tow the trailer (Figure 17.1A). The trailer rides low to the ground so that the height of the car above the pavement looks normal to the camera. The tow vehicle is equipped with a sound-baffled generator and various rails and platforms to which lights and cameras can be mounted. The largest trailers for this purpose have wings that can attach to either or both sides and are so wide that they require two lanes. The wings provide room for the camera, lights, and necessary crew. A limited number of crew are permitted to ride on a trailer and tow vehicle. It usually works out well to tie HMI ballasts to the speed-rail frame around the roof of the cab of the tow vehicle. Run cables along the speed rail, keeping them neatly tied and out of the way. Be sure that nothing will slip loose, rattle, drag, or get under the tires when the car gets on the road. The camera may be on the platform or mounted to the side door or the hood of the car, or mounted to the tow vehicle. Some very specialized vehicles support the camera on a crane arm, which makes placing the camera a relatively easy task and provides an opportunity to approach a driving scene with some dynamic camera moves (Figure 17.1B).

Many techniques are used for lighting the interior of a car. The basic problem with daytime car interiors is the contrast between interior and exterior. For a daytime scene, the light level on the faces has to be brought up so that the exterior scenery is not overexposed. When lighting a car on a sunny day, one approach is to use large HMI sources on the tow vehicle to simulate daylight on the actors' faces. Diffusion material is mounted on frames in front of the lights, or sometimes attached to the windshield (assuming that the camera does not see the windshield).

Free driving is perhaps the most challenging from the lighting perspective. The actor actually drives the car (with no tow vehicle or process trailer) and the camera operator is either in the front seat or back seat, or the camera is mounted to the door or the hood. For free driving, the gaffer must use batteries to power the lights. Chapter 16 provides practical tips for selecting, prepping, and using battery packs and inverter systems. A small, powerful, and adaptable fixture such as a Nila LED light or small HMI can be run on battery packs or inverters as discussed in Chapters 8 and 16. Shooting at night poses a different set of problems. For a city street scene, an open aperture is needed to make naturally lit storefronts visible. You would therefore shoot at relatively low light levels with small fixtures taped to the dashboard, or to the visor (an LED, or small fluorescent are commonly used for this). Some DPs like to employ additional lights to create reactive light—the light of passing traffic and streetlights by bringing the lights up and down on dimmers or panning them across the actors.

Set Lighting Technician's Handbook, 4e. DOI: 10.1016/B978-0-240-81075-1.00017-9

FIGURE 17.1

Rigging lights to a moving vehicle: (A) a car on a process trailer; (B) shotmaker truck towing a car.

(Courtesy Shotmaker Co., Valencia, CA.)

With fast film, the lighting need not consume a lot of power. A night scene could be very minimally lit using a couple of 12 V fixtures (Kino Flos, LEDs, stick-ups, Dedolights, or other 12 V fixtures) running off of the car battery or battery pack. In a pinch, I once liberated a headlight from the grip truck; bounced, diffused, and wrapped in blackwrap, it looked fantastic.

Poor man's process and other techniques

Other options for shooting driving shots don't actually involve driving. *Poor man's process* is the name given to nighttime driving shots using a stationary car and an array of light gags to simulate passing vehicles, vehicles following, passing street lights, and so on. The grips bounce the car a little, and the camera operator helps sell a little movement.

For nighttime shots, gaffers sometimes simulate passing streetlights with a “whirly gag.” This is two lights mounted to opposite ends of a 20-ft. piece of speedrail pipe, which is rotated around and around on a tall stand so that the lights pass over the car one after the other. The light from the fixtures comes onto the driver, travels down, and disappears as the light passes overhead, reflected in the windshield as it goes by. Although it registers for just a moment, you have to choose a light fixture that can pass as a streetlight (like a red head, or small fresnel) and keep any gel tidy in a frame. Another poor man’s process technique is to mount two very small lights (midgets) to a doorway dolly as if they are the headlights of a following vehicle on a dark highway. As the dolly is moved little left and right behind the vehicle very slowly, from a frontal camera position it appears that the highway has a bend, or the following car is changing lanes. To simulate the light of passing storefronts, lighting technicians with handheld fluorescent lights pan their lights on and off, while swinging the light to give it movement. The beam of an oncoming car might be simulate by using a stable moving platform (an electrician riding on a doorway dolly). The lamp operator tilts the light slowly onto the front of the car, lets it get brighter as it the dolly approaches the car, and then pans it off as the dolly comes past the front of the car. Every one has their own tricks for doing poor man’s process gags. Two additional techniques for making driving shots on a sound stage are rear-screen projection and green screen (matte photography). Both techniques require that the scene outside the windows be shot separately and either projected during filming or married together during postproduction. Lighting green screens is covered later in this chapter. These can be day or night scenes. For day scenes, the gaffer will sometimes put a light and lamp operator on a jib arm. As the crane slowly arms left and right, the sunlight appears to shift as if the car is turning.

LIGHTING IN AND AROUND WATER

Working in wet and damp locations presents an extra challenge for the electrical department. In this section, we’ll look first at how to handle electrical safety when working near water, and in wet and damp locations. This gives us a base of knowledge we then apply to the additional challenge of shooting under water. We’ll look at the protection equipment necessary to keep the set safe, and the specialized fixtures and techniques used to light it.

Working with electricity around water and damp environments

A *ground fault* is a condition where, due to a fault in the wires or equipment, the housing of an electrical device has become electrified and current from the device is seeking any path back to ground potential. The danger of water is that it greatly reduces the resistance between you and ground. In wet grass, moist soil, standing water, or a swimming pool, water is a conductor. Salt water (which is essentially what the human body is made of) is a better conductor than fresh water. Neither is a very good conductor, but both can still pose a threat to life if a ground fault exists. To get a shock, a person must become part of a closed circuit. When immersed in water, a diver becomes part of the ground. The greatest danger is to reach out of the water and touch a metal device that has an electrical fault in it. Electricity will travel straight through the body: in through the arm, through the lungs and heart, and out through the lower half of the body. This scenario could very easily kill a person. When

working in rain (real or manufactured) everything and everyone tends to get wet, and wet hands, gloves, and feet pose little resistance should you come into contact with a fault. A similar hazard exists any time the ground is thoroughly wet. In fact, water is a better conductor when it is mixed with the minerals of soil. A muddy field is more conductive than a freshwater pool.

To protect people from electrical hazard in wet locations certain precautions must be taken. Light fixtures must be properly grounded and GFCI protection must be used on all circuits that are in proximity to water. Connection points are elevated on "swamp boxes," milk crates, or apple boxes. Electrical connections can be protected to some degree by wrapping them in Visqueen or heavy-duty plastic garbage bags to prevent rain or splashed water falling onto them. When cable is to be run in wet areas, it should be inspected prior to use. Eliminate any cables with deep nicks or cuts in the insulation. Another effective way to protect cable connections that are not designed for wet locations is to wrap the connections with a silicone-based fusing tape such as Rescue Tape. This tape is applied by stretching the tape and wrapping it so that it overlaps itself. The tape is elastic, and stretching it activates a process by which it fuses to itself in a few seconds and creates a watertight seal. To remove the tape, it has to be cut with a knife, but it does not adhere to anything but itself, so there is no sticky residue.

Some equipment is designed with a certain amount of protection from water. The SL61 Socapex connector (monopiece backshell, by Amphenol-Socapex) is a waterproof connector (IP67—can be submerged on water up to 1 m deep). Any equipment with an IP rating for which the last digit is 6, 7, or 8 is well protected. Equipment that has a NEMA 3R or NEMA 4 rating is designed to the NEMA standard for outdoor use, which provides a degree of protection against damage to the equipment from ingress of water (see Appendix E for more about NEMA and IP ratings). Some Cam-Lok connectors are NEMA 3R- or 4-rated. Some companies make main Cam-Lok disconnects and spiders having a NEMA 3R rating. You can tell that they are 3R-rated, because both the *output* and *input* connectors are protected with flaps that spring closed. Most of the distribution equipment we commonly use is not rated for outdoor use, which is not to say that it can't be used outdoors—it just has no protection against dirt, dust, and water. Stage Pin (Bates) connectors, lug spider boxes, Edison plugs, and sockets provide no protection from water. These connection points must be kept away from water and raised and wrapped to protect from errant spray, splashes, or condensation as described earlier.

GFCI protection

It is a common misconception that a circuit breaker is there to protect you. A circuit breaker is there to prevent fire created by heat from an overcurrent or short circuit and protect the equipment. The amount of current it takes to electrocute a person is much smaller than the amount needed to trip a circuit breaker. An electrical shock current of one hundred milliamps (100 mA or 0.1 A) is a very serious shock capable of causing paralysis of the lungs and heart muscle. The smallest circuit breaker we use is 20 A—that's about two hundred times more current than is needed to kill you.

To protect against serious harm from electrical shock, the circuit must be monitored by a Class A GFCI (Ground Fault Circuit Interrupter). This type of device will interrupt the circuit if it detects current leakage that is greater than 6 mA. At 6 mA, almost all adults and children can let go of the source of the shock. At higher currents, people are progressively less able to overcome muscle contractions caused by the shock, and therefore less able to disconnect themselves from the fault source. A GFCI will deenergize the circuit in less time than it takes to receive a harmful amount of current. Any time electrical equipment is to be used in close proximity to water, GFCIs should be used for the circuits powering that equipment. Around a pool or tank, we know from experience

that when divers or actors are getting in and out of the pool, water is going to splash and drain in all directions. Therefore, electrical gear anywhere nearby must be protected by GFCI. Any time lights are suspended over water, they must be GFCI-protected. Even though the lights are hung securely and use safety cables, one has to protect against electrifying the wet surfaces in the event of a failure or accident. This also applies to any and all electrical tools and devices used in close proximity to water such as work lights, hair dryers, heaters, vacuums, compressors, pumps 120 V drills, and so on.

When working around water, one person in the set lighting department must be designated to monitor the set continually for electrical safety and handle the power needs of other departments. A worker may decide to place a work light (not protected by GFCI) right next to the pool. Someone may try to run over the HMI cables with a heavy cart. Someone may try to plug into a GFCI and trip it with a piece of untested equipment. A designated lighting technician has to remain on set at all times when the circuits are energized with his or her eyes open. This may be the gaffer, if duties allow him or her to remain at the site, or another lighting technician. It doesn't matter who it is, as long as they are aware of their responsibility and replace themselves before leaving the set.

GFCI devices

Shock-Block (Littelfuse) and Bender are both manufacturers of GFCI systems for use in various industries. For our industry, they have developed a variety of devices to provide for almost all our common distribution scenarios (see Table 17.1).

In order to provide GFCI protection for an entire distribution system, the system is divided into tiers. The final level of GFCI protection must be a Class A GFCI device to provide protection for personnel (Figure 17.2). Higher amperage GFCI protection can also be installed upstream of the Class A devices. These are typically Class C GFCI devices, which do not provide protection at a low enough current to protect personnel, but are installed at the major distribution junction points to provide ground fault protection for the cable and distribution equipment (Figure 17.3). Using a coordinated system of devices in which the trip time and trip current are lower on the GFCIs near the load and higher on the GFCIs toward the source, the system assures that the downstream elements trip before the upstream elements. This arrangement assures that if a hard short occurs at the load, the GFCI immediately upstream of the short trips and removes the fault current before any larger circuit protection upstream trips, thus preempting a larger power outage. The effect is to isolate and keep the problem circuit from bringing the whole system down.

Almost all electrical devices leak some current. When many lights are used, these small amounts of leakage can add up. This is the primary reason that it is better to use many small GFCI circuits rather than ganging lots of lights onto one larger one. Many GFCIs provide an indication of the leakage at any given moment—a chain of five LED lights that display the level of leakage for example. This helps the lighting technician know when the total leakage is approaching the maximum allowed by the GFCI, and helps identify loads that leaking badly. By monitoring the LEDs while equipment is plugged and unplugged, an electrician can discover the amount of current leakage due to a particular load. The electrician can use this information to separate the loads on different GFCIs to prevent unnecessary tripping, or to eliminate loads that have too much leakage. Many GFCI units also monitor ground presence and power phasing. If either of these is not correct, the unit does not reset and identifies the problem on its display.

Table 17.1 GFCI equipment

Type	Amperes (A)	Total amperes (A)	Volts (V)	Connector (in and out)	Manufacturer
Class A GFCI	20	20	120	Edison	Bender
Class A GFCI	5 × 20	100	120	100 A Bates-in, Edison-out	Bender
Class A GFCI	6 × 20	120	120	Socapex	Bender
Class A GFCI	100	100	120	Bates	Bender Shock-Block
Class A GFCI	100	100	240	Bates	Bender Shock-Block
Class A GFCI	3 × 100	300	208/120	Cam-Lok-in, Bates-out	Bender
Class A GFCI	100 per phase, three phase	300	208/120	Cam-Lok	Shock-Block
Class C	200 per phase, three phase	600	208/120	Cam-Lok	Shock-Block
Class C	250 per phase, three phase	750	208/120 or 480/240	Cam-Lok	Bender
Class C	400 per phase, three phase	1200	208/120 or 480/240	Cam-Lok	Bender Shock-Block
Class C	800 per phase, three-phase	2400	208/120 or 480/240	Cam-Lok	Shock-Block

Shock-Block units can be used on a dimmer line, downstream of the dimmer. Some Bender units require power to operate, so Bender makes special dimmable units that have an auxiliary power input to power the GFCI device. Inquire with the manufacturer.
Some of the larger units can be switched over for use with 480 V power. This is accomplished with an internal switch that should be set at the manufacturer's facility.

Testing the equipment

As a matter of safety, and because you don't want the GFCIs to be tripping all the time, all the electrical equipment has to be thoroughly tested for leakage current before being is used with GFCIs. This includes stingers, lights, cables, or any other electrical equipment that is expected to be used on a GFCI. Prep time should be allocated for testing.

There are a number of ways to go about testing for leakage current:

Current Leakage Meter. Fluke, Hioke, and others make clamp-on meters for leakage testing (Figure 17.4A). These are specialized meters capable of detecting very small current differentials. They give a read-out of the exact amount of leakage detected.

Inline GFCI (6 mA). A simple, practical test method for small lights and stingers is to plug into a 20 A portable GFCI unit (Figure 17.4B). The GFCI will trip if it detects greater than 6 mA of leakage current. This will not tell you anything about leakage smaller than 6 mA, but it eliminates equipment that has a significant ground fault. You can use a 100 A GFCI to test larger lights.

e-cart. An e-cart (Figure 17.4C) is a testing station equipped with every kind of connector and provides current leakage information for whatever is plugged into it.

FIGURE 17.2

Class A GFCI personnel protection. (A) 100 A Class A GFCI. A small display on the front of the unit shows the level of current leakage. Three buttons on the side control the contactors. (B) This unit provides Class A GFCI protection for six circuits in a Socapex cable. Each unit incorporates a test button to check whether the GFCI is working. It also has an OFF button and a RESET/ON button.

(Courtesy Lifeguard by Bender, Inc.)

FIGURE 17.3

Class C GFCI system protection. This unit has a capacity of 400 A per phase at 208, 240, or 480 V (with or without neutral).

(Courtesy Lifeguard by Bender, Inc.)

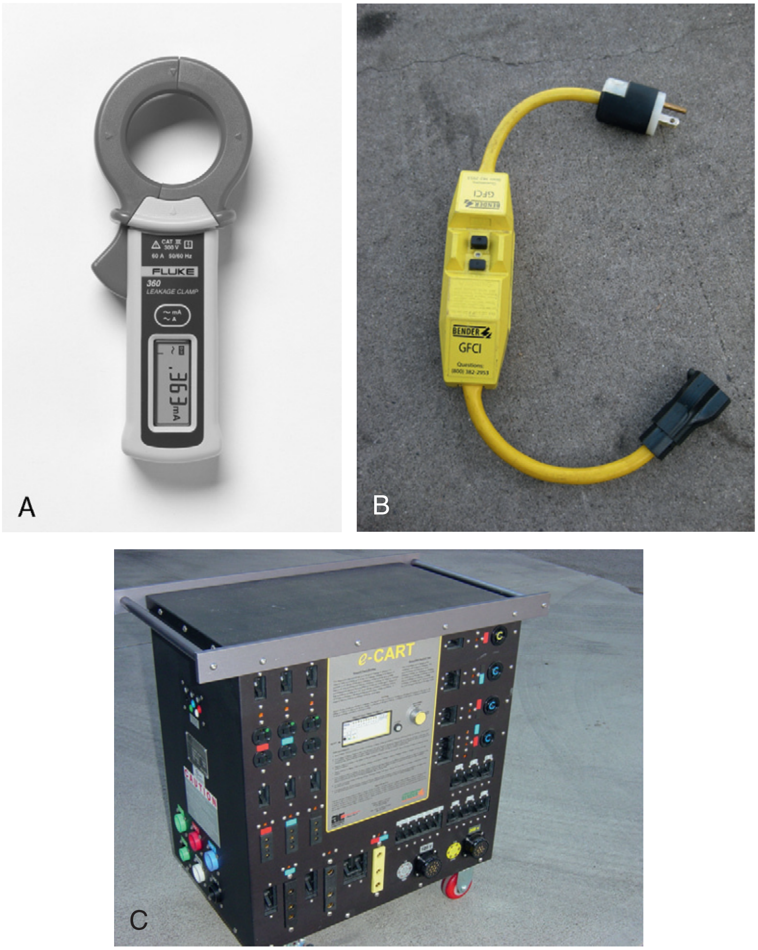

FIGURE 17.4

(A) Fluke leakage tester (Courtesy Fluke); (B) inline waterproof Class A GFCI; (C) e-cart. (B and C Courtesy Lifeguard by Bender, Inc.)

AC/DC switches like those on tungsten 10k lights have been known to trip the GFCI when switched. You may have to leave the light switch on, and turn the unit on and off from the distribution box or the GFCI. Experience has shown that it is very often homemade equipment and cables that develop a problem. The earth leakage may be due to a piece of gear used by the sound department, video playback, or effects department. Practical lamps are also a common source of earth leakage current. Of course the personnel in those departments will swear up and down that their equipment is not causing the problem; if you have one of these testing options handy, you can help them confirm their claim—or not.

Shooting in the rain

In addition to providing GFCI protection one of the primary concerns when shooting in the rain—real or artificial—is that the lights are protected from falling and blowing moisture. If water falls or blows onto the hot lens, the thermal shock can crack or shatter the lens, especially when the bulb is in flood position, where it makes the lens hottest. If water leaks into the housing and touches the globe, the globe will burn out or explode. With HMIs, water causes serious problems with the electronics. Water can also cause corrosion to the metal parts of the fixtures. Some lights are designed to shed water to some degree while most are not (see Appendix E).

Protect the lens with a gel frame of heat-shield gel or a thin color (⅛ CTO or ⅛ CTB). Place rain hats over the lights. Rain hats can be made out of Celo screen (a tough, plastic-covered, wire screen); a flag covered with a garbage bag works for small lights; a four-by flag wrapped in Visqueen for bigger lights. Poly Storm is a special material that can withstand extremely high temperatures. It is ideal for rain hats, because it is not prone to melt or catch on fire like Visqueen-covered flags. A 12-by or 20-by griff is handy to cover a number of units at once. (Check for holes in the griff first.) Rain hats should be positioned so that rain runs off away from the fixture; don't let rain collect and form a pool in the flag.

Lighting rain

Rain shots are typically created using rain towers (provided by the special effects department) or pipes suspended over the acting area. The effects supervisor will typically be able to give the gaffer a good idea where he or she expects the water to fall. Falling water is most visible to the camera when lit from the back. Falling water will not read very well when lit from the front.

UNDERWATER LIGHTING

The old drop-a-bulb-in-the-pool method

When it comes to designing underwater light fixtures, there are additional problems and safety issues that arise. In the days of Esther Williams, it was standard procedure to light water ballet sequences by submerging bare 10k incandescent bulbs in the pool. The power was DC. The feeder cable was soldered to the terminals of the globe, and the connection was potted with a big glob of epoxy or latex rubber to make it watertight. (In the early days, they used tar.) As daring as it may sound, the idea of using standard lamps (later, PAR lamps were used) with a watertight electrical connection was a predominant method of underwater lighting until the 1980s. Gaffers have even been known to light an (empty) swimming pool at night by simply dropping a standard tungsten lamp into the pool. This is not a good idea for many reasons: (1) risk of electrocution should someone accidentally fall into the pool, (2) tungsten halogen globes blacken with tungsten deposits in a matter of hours when surrounded by water (water-cooling prevents the halogen cycle), (3) electrolysis corrodes all the metal parts of the light and destroys it.

I mention these experiences because they illustrate the practical problems involved in putting lights and live leads into water. For starters, if the bulb burns out, you have to pull up the whole cable to solder on a new globe, which creates a lot of downtime. Second, having a large amperage running through every cable increases the danger posed in the event that a hot wire contacts

the water. Third, the bulbs must be submerged before they are turned on, because the temperature differential between the hot globe and the cool water can cause the glass of a bulb or par lens to crack or explode. Finally, if the bulb breaks under water, the result is an electrified conductor in contact with water.

The developments in underwater lighting and camera housings in the 1990s turned a corner for this specialization of filmmaking. Lighting underwater became safer and more efficient. Simultaneously, new equipment greatly expanded what is possible underwater and improved the quality of underwater cinematography. Underwater lights have been put to work in swimming pools, in large water tank sets, in lakes, and in the open ocean. Underwater lights are often enlisted to light up swimming pools or fountains. A light placed at the bottom of a pool makes the entire thing glow and throws moving highlights on surrounding people, set dressing and architecture. The lights work great in rain scenes, flood scenes, and storm scenes aboard ships, in which gallons and gallons of water may pour across the deck. These can be treacherous sets to shoot, because with wind and water, things can easily get knocked down. Deploying underwater units in water-laden areas of the set greatly reduces the risk of electrical accident, should a light be knocked into the water or broken.

Electricity in water

A bare wire underwater sets up an electrical field around it as it seeks all paths to complete a circuit (to ground or the neutral wire). The primary route is the path of least resistance. If the neutral or grounding wire is close by, as in the case of a sheared cable, the field is very strong between the two wires and spreads around the fault, weakening with distance. The size of the field depends on the amperage available and the impedance imposed by the size of the wires. This is the reason why it is better to use lots of lower-amperage cables rather than a few very high-amperage ones. For example, if a 10 A circuit power cord in fresh water gets cut by a boat propeller, water sets up a field with a diameter of about 5.6 ft. (minimum safe distance). A cable carrying 100 A, on the other hand, sets up a field 49 ft in diameter.

Another reason many low-amperage cables are preferable to a few high-amperage ones is that GFCIs on 20 A circuits are very dependable. The higher the amperage, the greater the noise in the system and the less dependable the GFCIs become. You get more nuisance trips.

A diver can feel it when he or she is coming close to an electrical field. If you ever put your tongue on a 9 V battery, you know the taste, and you can feel a tingle in the fillings in your teeth. Closer to the field, you begin to feel the tingle of electricity in your body. A diver inside a strong field may experience the effects of electrical shock: trouble breathing, muscle freeze, cardiac fibrillation, and cardiac arrest.

Modern underwater fixtures

For an underwater lighting system to be safe, it must: (1) be a completely sealed system, watertight from cable to bulb; (2) provide a sensing device and shutdown mechanism in case an electrical fault occurs; and (3) overcome the problem of thermal stress on the glass that is in contact with water.

James Cameron's epic adventure film *The Abyss* revolutionized underwater lighting technology. Forty percent of the live action footage was filmed underwater in a huge tank 209 ft in diameter and 55 ft. deep. The project offered two young inventors the opportunity to realize a project they had had

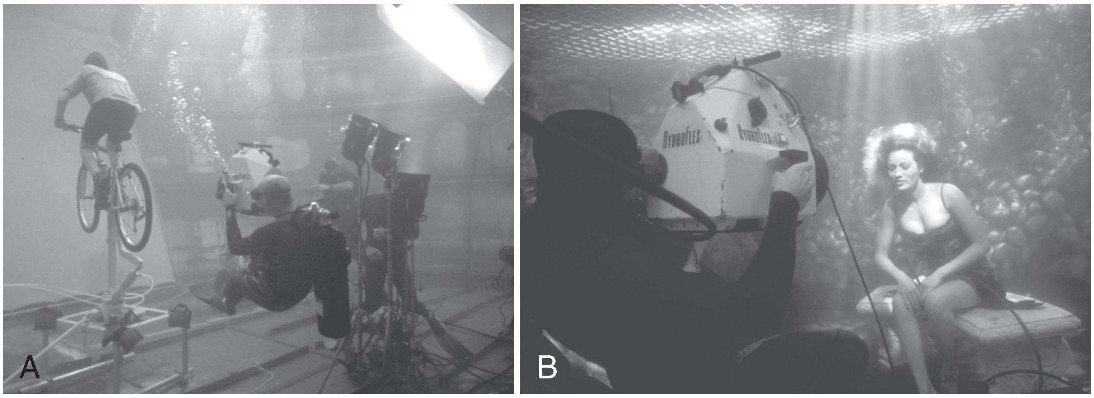

FIGURE 17.5

(A) Underwater lights bounced into a white reflector light an underwater green screen shot. (B) Light streams through a lattice floating on the surface for this shot from a music video.

(Courtesy HydroFlex Inc., Los Angeles, CA.)

in mind for some time. Pete Romano, an underwater cameraman, and Richard Mula, a gaffer and engineer, developed the 1200 W HMI SeaPar, an efficient underwater PAR light, to meet the needs of this extremely demanding project (Figure 17.5). The SeaPars work equally well out of water, in the rain, or submerged to depths of more than 250 ft. Subsequently, a whole line of tungsten, HMI, fluorescent and LED lights sprung from this initial system, which are now available from HydroFlex.

The system is watertight. Ballasts and main distribution cables remain above the surface. The head cables run down into the water. The lights use watertight plugs that can be plugged and unplugged underwater with the power off. The connectors have locking sleeves to prevent kick-outs. Divers are protected from the hazard of a lead that is unplugged being accidentally energized under water because the female plug naturally holds air within the deep contact pockets so that electricity does not come into contact with water. All cables and connectors are watertight. The connection point on the head is made so that even if the head cable gets cut, water cannot enter the head.

To provide a fault-sensitive shutdown mechanism, the system operates on AC current with a grounding lead. All metal parts are grounded. The HMI ballasts are fitted with two Class A GFCI devices that sense the presence of leakage current. If there is more than a 5 mA differential between the hot leg (outgoing current) and the neutral leg (return current), indicating that fault current is leaking through to ground, a relay cuts power to the ballast. This is less current than required to harm an individual, even if the person is in contact with the fault source.

The second GFCI serves as a redundant backup. In addition, a fourth lead is used: a ground-return lead connected to a relay circuit constantly monitors the integrity of the grounding lead and shuts down the power if the ground is removed or lost. Finally, the outside glass covers on these fixtures are made of special thermo shock-resistant glass that can withstand sudden extreme temperature changes.

The underwater lighting arsenal

An entire line of underwater HMI, tungsten, fluorescent, LED, and xenon light fixtures are available commercially. HydroFlex offers tungsten pars in 5k SE, 2k SE, 1k (PAR 64), and 650 W (PAR 36) sizes, as well as a small MR16 fixture. HydroFlex also offers various HMI pars, including 4k SE, and 1200 W SE Hydropars PAR. An 8k HMI broad/cyc fixture called the *HydroRama* employs twin axially opposing 4k SE globes set in a reflector. This is a very bright broad fixture, good for lighting large areas, large sets, or green screens. The HydroRama fixture is adaptable to take twin 5k SE bulbs, making it a 10k tungsten-balanced broad/cyc light. The larger fixtures may not be used out of water, as they depend on water-cooling.

A Litepanels 1×1 LED fixture adapted for underwater use, the SeaSun, is a handy fixture for hiding in small sets such as a sinking car. This is a 5600 K unit weighing 1 lb in water that can be used in or out of water. It makes a good handheld soft light.

HydroFlex has several self-contained flashlight fixtures that can be used either by actors on camera or as a small off-camera fill light. Among them are the 21 W MHL Splashlight (daylight-balanced) and the 100 W tungsten Hartenberger (dimmable to three settings). HydroFlex adapted many of the familiar Kino fixtures for underwater use. The lights include the HydroFlo 9-in. kit; 6-ft., 4-ft., 2-ft., 15-in., and 9-in. individual tubes; 4-ft., four-bank and 4-ft., eight-bank and 15-in., two-bank (Mick Light) soft boxes; and 4-ft., four-bank and 4-ft., eight-bank panel lights for lighting green screens.

Other options for underwater lighting are also available from Pace. Architectural submersible fixtures such as the Color Kinetics C-Splash (RGB color LED fixture) are designed to be used in fountains and pools.

Features of underwater fixtures

It is a property of physics that spreader lenses have very little effect if they are on the outside of the fixture, surrounded by water. Underwater pars that use spreader lenses have to house their spreader lens inside the watertight cover glass. Spreader lenses can be exchanged (out of water) by simply unbuckling the cover on the front of the fixture.

The 4k HMI Hydropar and 5k tungsten Hydropar do not use spreader lenses. Instead they have interchangeable spot, medium, or wide reflectors (which can be exchanged in or out of water without disturbing the sealed globe envelope). The 2.5k HMI and 2k tungsten Hydropar use changeable Fresnel lenses, which are inside the buckled fixture and must be changed on dry land. The larger fixtures cannot be used out of water, or only for timed periods.

Surface support

When divers are lighting underwater, there should always be a support person stationed at the surface close at hand. This person is there to hand equipment down the divers as needed, but they can also do a great deal to save the diver from having to make trips to the surface. If a light trips off, a surface support person who is paying attention can take note check for problems at their end. If a light stand is no longer in use, the diver can extend the stand out of the water while remaining at the bottom so that it can be pulled out from above. The support person can monitor GFCIs leakage current levels when lights are being added to avoid trips. This person also keeps track of the cables coming out of the water and makes sure that they are labeled. Lights should be labeled for easy identification underwater. With par lights, for example, the beam width of the lens of reflector (WFL, MED, NSP, VNSP) should be written on the top front of each head using 2-in. white electrical tape and a fat-tip Sharpie.

Acting as surface support can involve many hours of doing very little while a small crew works underwater. But it is a necessary and important job, because the diver's work is very physically demanding. It is important not to get pulled away or abandon this position without getting another electrician to cover. Nothing is more disheartening to a diver than to emerge from a long period under water needing assistance, only to find that everyone has wandered off.

LIGHTING MATTE PHOTOGRAPHY

It seems like almost every film and TV show we work on requires at least a few composite shots using a green or blue screen. For a composite, the foreground action and the background action are filmed separately, and then combined to make it appear as if the two coexisted in the same space and time. For example, consider a shot of a man dangling by his fingertips from a 40th-story ledge with ant-like taxicabs visible far below. This is two shots: (1) the *plate* shot, the background, a view from the 40th floor looking down at the taxicabs in the street with no ledge in the foreground (the plate shot could even be a miniature model), and (2) the foreground action, a shot looking down at a man dangling from a ledge with a matte screen behind him. The singular color of the matte screen (typically blue or green) allows the foreground element to be cleanly separated by digitally removing that very specific color, allowing the plate to take its place in the background. The composite is made by scanning the two shots at very high resolution into a computer and compositing them digitally. For the two shots to be wed effectively, there are a number of considerations for lighting.

Pure screen color and density

The details of how the colored screen is removed and replaced with the background plate are beyond the scope of this discussion, but suffice it to say that the compositor is able to get the best results with the purest color screen, especially in separating fine detail like blowing hair or transparent elements like smoke. If the screen is contaminated with other color, shadows, or differences in saturation, it is much more difficult for the compositor to retain fine edge detail, and the matte will not look good or the image may need to be cleaned up by rotoscoping frame by frame. Rotoscoping is a time-consuming, expensive solution. Most often, it is far easier and cheaper to take the time to light a clean, pure matte screen on set.

Special effects professionals have developed a number of ingenious ways to produce the purest possible matte. They start by controlling the color of the screen and the lights and refining them to a very specific single color, usually a specific green, but maybe a blue or red. Composite Components, one of the central innovators in compositing, developed the Digital Green™ screen and Digital Green™ paints. The color of the screen was reverse-engineered by looking at the spectral sensitivity curves of particular Eastman Kodak film stocks to find a narrow portion of the color spectrum where the film captures the purest color (best localized to one color layer of the emulsion). They then designed fluorescent tubes that radiate only in the same spike of spectral energy. These tubes are extremely bright in their selected part of the spectrum (around 436 nm blue, 545 nm green). Flo Co. manufactures and distributes these tubes in Digital Green™, Digital Blue™, and Digital Red™ along with their own fixtures. Kino Flo also supplies special green and blue fluorescent tubes for lighting green and blue screens. Kino Flo's effects tubes are off-the-shelf tubes originally

manufactured for another purpose, yet they produce a very pure color output (green 560 nm or blue 420 nm) and fully saturate the matte color.

The matte screen must be lit evenly. The compositor relies on uniformity in density to produce good separations. One should shoot for a variation across the visible section of the matte screen of not more than a stop. At one time, this was done quite effectively by lighting a transmission screen from the rear with panels of fluorescent tubes. With bigger and bigger matte screens being required, this system became impractical. Front-lighting a solid green or blue screen using fluorescent fixtures yields very good results and has become the norm. Because fluorescent banks produce such soft light and the green or blue tubes are so surprisingly bright, fluorescent fixtures are more than adequate to front-light even a very large matte screen. A row of evenly spaced 4-bank, 4-ft fixtures along the bottom and top of a 20-ft high matte screen typically produce an adequate brightness. With larger screens, you can bump up to 8-bank or 10-bank fixtures. Using DMX512-controlled fixtures allows easy adjustment the screen brightness as needed. Egg crate louvers, diffusion, door extensions, and blackwrap can be handy to help even out the light from top to bottom.

Lighting the foreground

The foreground lighting must make the subject appear to be in the same environment as appears in the background plate. Contrast and color temperature should be matched as closely as possible. Attention to the direction and feel of the key light and the kind of ambient light shown in the plate shot are important when lighting the foreground shot.

Backlight, edge light, or sidelight is important with matte shots. Keep in mind that, when the background is dropped out, the foreground subject may as well be standing in black limbo. If the background plate is of a bright environment, some of that light should appear to be hitting the subject in the form of edge and backlight. Backlights also help wash out any green light wrapping onto the actor from the screen, which can contaminate the matte.

Some forethought is required in hanging the backlights. The lights must be arranged in such a way that the fluorescent lights front-lighting the matte screen and the backlights do not interfere with one another (Figure 17.6). They often want to occupy the same place or cast shadows of one another.

The foreground lighting has to be kept completely off the matte screen, and the matte screen has to be kept completely off any reflective or glossy parts of the foreground subject. Reflections of the matte screen appear as holes in the matte. Contamination on the matte screen makes it hard for the compositor to pull a good matte. To keep front light off the matte screen, *allow plenty of space between the screen and the foreground action—15-25 ft*. It is a common mistake to underestimate both the size of the screen and space in the soundstage needed for matte screen shots. These shots also require more floor space for flags in front of the front lights to cut white light off the background.

Masking off the matte screen where it is not needed reduces reflections of the matte screen in props, set dressing, and wardrobe. Dulling spray can be used on shiny objects. White cards and flags can be set around the edges of shiny objects to block the reflection. These can be removed in post production using a quick crude matte called a "garbage matte." The compositor can remove the grip equipment from the shot later, as long as it is separated from the subject by the green background. Angle them so the card or flag is reflected in the shiny surface from the camera's viewpoint instead

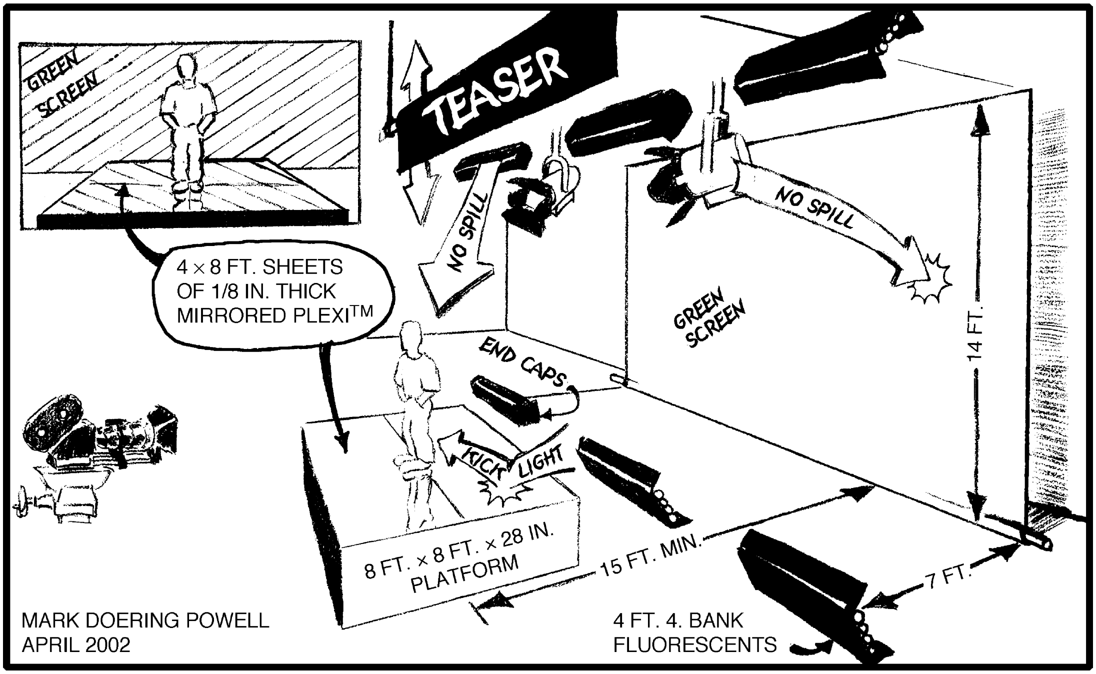

FIGURE 17.6

Using the thinnest possible Mirrored Plexi™ sheets on a small platform under the actor, the camera sees a seamless matte color background all the way to the actor's feet. At the bottom, the screen is rolled onto a pipe to hold it flat to the ground (ties would be seen by camera). The fluorescent fixtures lighting the screen from below and above are placed a distance away from the screen (7 ft., in this case); for even coverage, it works well if this distance is about half the height of the matte screen (14 ft.). The lights are spaced no more than 3 or 4 ft. apart and must extend beyond the edge of the screen to light the screen evenly all the way to the edge. Each fluorescent is capped on both ends with blackwrap to prevent spill onto the actor. Note that all the lights must be flagged, teased, or wrapped in blackwrap to prevent spill from the foreground onto the background screen and vice versa, as are the lights lighting the actor (not shown here). The backlights cannot be placed where they will block the upper fluorescent lights. If there were more space behind the matte screen, the backlights could also have been hung there, which also helps prevent spill back onto the screen. Note that the backlights kick off the mirror floor onto the actor's legs. This can be helped with judicious use of bottom barn doors and black wrap or flags. The teaser is adjustable up and down and so that it can be placed to keep all the backlights from flaring the camera lens.

(Illustration by Mark Doering-Powell.)

of the screen. Note: shots of curved chrome-like objects may have to be dealt with using another compositing technique, because depending on the shot and the action, it may be impossible to properly contend with reflections.

Matte photography poses many even more complex lighting challenges. For example, when an actor is to be seen from head to foot walking around in a virtual set, the matte screen behind the actor must seamlessly meet the floor under his feet. This can be accomplished by laying out a

mirror-plex floor, which reflects the green screen to camera (Figure 17.6). This can be a very effective technique. Precautions must be taken to allow the screen and the mirrored floor to meet seamlessly. Also, the backlights will want to kick onto the actor's legs off the floor, requiring lots of subtle grippage and time. The compositors have to rotoscope where the actor's feet touch their own reflection in the mirror. However, making this small concession to have an otherwise clean matte is far preferable to the alternative: lighting the green set, the actors, and the screen with the same (white) light, which creates even more challenges for the DP and the compositor.

HIGH-SPEED PHOTOGRAPHY AND CAMERA-SYNCHRONOUS STROBES

Both Clairmont Camera and Unilux, Inc., offer high-speed strobe lighting systems that synchronize the flash of the lighting units with the shutter of the camera. Each frame of film is given a very bright, very short flash of light. When a camera operates at 24 fps, the exposure time is normally $1/48$th seconds. With the Unilux strobe unit, the flash is $1/100{,}000$th seconds. When the strobes are the sole source of illumination, the effect is to remove all motion blur from an image. Strobe units are often used for shooting slow-motion close-ups of pouring liquids, such as in beer and soft drink commercials. Each drop of beer is sharp, because in each frame the moving drops are frozen in a microsecond of flash. The lights can be synchronized with the camera shutter at frame rates from 1 up to 650 fps. The strobe system synchronizes to the speed of the camera using a sync cable connected to the camera's speed control accessory receptacle. The strobe speed follows the camera shutter speed to give one flash each time the shutter is open and one flash each time it is closed, which, with a film camera, is when the camera operator can see through the lens.

In many instances, cinematographers find that the strobe by itself is overly sharp. To make the image look more natural, you can mix strobe with tungsten or flickerless HMI sources. A good mix is to set the strobe two stops brighter than the supplemental sources. When taking light meter readings from strobes, a special technique has to be used. You will find more details about using strobes at the manufacturer's Web site, and there is a short technical article about strobes on the *Set Lighting Technician's Handbook* Web site.

Unilux strobes (Figure 17.7) have been used to create other effects as well. By using a special-effects generator box, the lights can create a flashing strobe effect by not exposing every frame. This appears on film as a series of flashes with performers jumping suddenly from one position to another. Using a sequencer circuit, the lights can also be made to chase so that in each frame light comes from a different head. This effect has been used in music videos, for example, to create a disco strobe effect or to capture dance in an ultra-sharp, jerky style. Strobe effects have also been used to create the flashing light of a train passing in a tunnel on feature films such as *Throw Momma from the Train* and *Jacob's Ladder*.

FIGURE 17.7

The Unilux H3000 system pictured here has five heads, two control units, and shipping case.

(Courtesy Unilux, Inc., Hackensack, NJ.)

CHAPTER

Specialty lighting equipment

18

BIG GUNS

From its very beginning, motion pictures have used big lights. In the early days of motion pictures, use of carbon arc lights allowed production to be moved indoors. At that time, film stocks were not sensitive enough to produce an exposure at light levels much less than that of daylight. It is perhaps ironic that even with today's technology, the market still has a need for bigger and brighter lights. Despite the fact that film emulsions and video sensors are 16 or 32 times more sensitive than they were 75 years ago, we still have a need for lights that are an order of magnitude brighter than even a carbon arc. As technology has advanced, filmmaker's ambitions have expanded, too.

To meet this demand, manufacturers are always trying to design bigger, brighter, and more efficient lights. The problem is always heat. I was told once that in the 1960s at one of the studios, someone actually built a 50,000 W tungsten lamp. It was water-cooled. Only one was ever made and reportedly it was only used once. In the *Professional Lighting Handbook* (2nd ed., Boston: Focal Press, 1991), Verne and Silvia Carlson describe an early prototype 18k HMI fitted with cooling air-jets and foam aluminum heat sinks. If air circulation wasn't just right, the lamp "had been known to warp reflectors, crack lenses, and vaporize the interiors of the fixture, as well as melt electrode tips." The efforts of these developers combined with space-age materials and refinements has brought incremental increases of lamp wattage and reflector efficiency over time. As mentioned in Chapter 8, advances in HMI lamp technology from 12 to 18 kW HMI pars and 24 kW (and possibly 36 kW) Fresnels give us the brightest conventional lights available. There is one light bigger, however.

SoftSun

SoftSun fixtures come in sizes from moderately large to enormous (3.3k, 3.6k, 10k, 25k, 50k, and 100k, which are all rectangular fixtures, and a 3.5k round par fixture). They are daylight-balanced (5400 K), flicker-free, and can be dimmed from their power supply from 100% to just 5% via a handheld digital remote control (or any DMX512 control signal). The color temperature is virtually unchanged by dimming. Most models are rectangular in shape, to accommodate the linear ESL lamp (enhanced spectrum long arc). Thus, the SoftSun lamp and reflector form a large-aperture direct light source (Figure 18.1). The rectangular units have a wide spread horizontally (most models 100° or more) but a focusable vertical spread (the 50k unit has an 11° spread in spot position and 35° spread in flood). Though these units normally are oriented horizontally, they can be deployed in any orientation. The 3.5k unit has a softer quality due to its large round parabolic reflector.

Set Lighting Technician's Handbook, 4e. DOI: 10.1016/B978-0-240-81075-1.00018-0

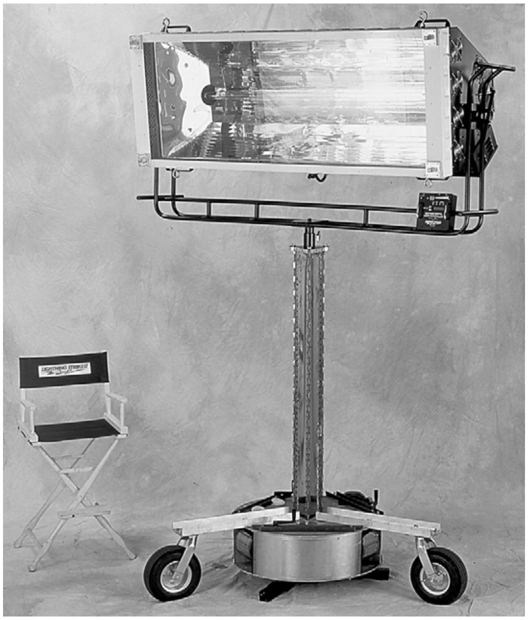

FIGURE 18.1

50k SoftSun.

(Courtesy Luminys Systems Corp.)

The larger SoftSun units have proven themselves invaluable for day exteriors to help create a consistent sun source, especially when the real sun ducks in and out of clouds or sinks behind the horizon. In these changing conditions, the dimming feature is especially helpful for maintaining balanced light levels. Because of its greater power and spread, the light can be backed up to cover more area with a single source. Compared to an 18k HMI at full flood, the 50k is approximately a two-thirds stop brighter (at full flood) to two stops brighter (at full spot). Due to the light's wide horizontal spread, it can replace two or three 12k or 18k Fresnels. DPs sometimes find this advantageous, because it allows them to deploy a single source which can help create a more natural look.

The 3.3k unit has proven especially good for lighting car interiors. SoftSun lamps pose no explosion hazard, and the lamps are shock-mounted and rugged enough to survive a high-speed chase. The size and shape of the 3.3k lends itself to lighting through car windows (26 in. long, 12 in. high, 9 in. deep). It weighs 24 lbs.

The ESL lamps keep consistent color temperature as they age, and therefore they also match lamp to lamp. They also remain consistent (within 100 K) throughout their dimmable range. The spectral power distribution is regular with no spikes, which shows a truer match to daylight than other daylight sources. The CRI is 96 or better.

The 50k and 100k units are very large (the 50k is 82 in. long, 33 in. high, 23 in. deep) and heavy (the 50k head weighs 210 lbs., the 100k weighs 300 lbs.). The bail is equipped with three 1⅛-in. junior pins: center and outboard sides. The light is most stable placed on two side-by-side super

cranks, although a single Cinevator can handle the 50k. Very often, the necessary flexibility is gained by placing the fixture in a Condor so it can be easily moved around, on the arm. Especially on uneven terrain, moving the light on two stands is difficult.

All the larger SoftSun units have Cam-Lok tails. The 50k flicker-free ballast requires a three-phase power 208-240 V AC at 220 A per leg (three phase wires plus ground), 50/60 Hz. So be prepared with 4/0 cable to power this light. The 100 kW runs off a 480 V three-phase generator (380/415 in Europe). Many generators of this size are switchable to 480 V. This also allows the 100 kW unit to still use 4/0 cable feeds.

All the SoftSun heads have quiet-running cooling fans.

Carbon arc lights

From the very earliest days of motion pictures, carbon arc lights have been lighting movies (Figure 18.2). In their heyday, there were quite a variety of arc fixtures, from Fresnels of various sizes to broads, ellipsoidal spotlights, and follow spots. Pick out any movie in the Classics section of your video store and you will be watching a film lit with arcs. The silhouette of a Brute arc is a Hollywood icon. In the 1970s, arc lights started to be replaced by another type of high-luminance daylight technology: the HMI. Discharge sources had clear advantages over carbon arcs. Each arc light requires a full-time operator. The carbons must be constantly trimmed and changed every 20-30 minutes. The lights must be shut off whenever possible to save the carbons and prevent excess heating. The phrase "Lights, camera, action," comes from the days when the lights were turned on immediately before each take. Arcs are noisy and make smoke. They run on DC power. With today's general shift to a more thrifty and speedy mode of production, arcs are rarely used. They sit in rows

FIGURE 18.2

Carbon arc light in use on set.

(Courtesy Mole-Richardson Company, Los Angeles, CA.)

on the top shelves of the studios' lamp docks, dusty hulks, relics of a time gone by. But still, every once in a long while, a film or commercial will haul out the Brute arcs. Why? Ask any gaffer or DP who worked with them. The quality and color of an arc is beautiful; no other source truly replicates it. Many gaffers consider them the nicest of all sources. A full explanation of how to run a carbon arc is available at the *Set Lighting Technician's Handbook* Web site.

LIGHTING BALLOONS

By placing HMI or tungsten lamps inside sealed diffusion balls, filling them with helium, and floating them over the action areas, you can create soft 360° light without the need for a high platform (Figure 18.3). Lighting balloons are particularly well suited for illuminating large delicate interior locations, such as an old cathedral or historic building, where rigging lights could damage the location. Lighting balloons are also often used simply for time efficiency, because they can eliminate rigging time and are relatively easy to adjust and move.

Balloons are often enlisted to create soft-light ambiance on exterior night scenes. For this application, balloons may afford the DP some advantages over rigging large lights in a Condor, depending on the desired look. Balloons provide a more even light, with softer shadows, and spreads 360° with a gradual falloff. For night exteriors, the softer look helps disguise the presence of artificial lights.

FIGURE 18.3

Here, lighting balloons provide ambiance under the thick canopy of a Hawaiian jungle. They are much faster to move around in the dense undergrowth than 18ks on stands. The gaffer also used these 6k balloons as key light by bunching two or three and employing soft-frost diffusion. As an added bonus, the balloons could be floated to soften direct sunlight when the grips would have had a hard time flying a diffusion frame.

(Balloons by Aerial Brilliance. Photo courtesy Mike Bauman.)

This is especially valuable in wilderness or rural settings, where the only motivated ambient source is moonlight. A soft source is also useful in urban scenes to lessen specular glints off of parked cars (although you have to watch out that the balloon is not visible in reflections in car windshields). Balloons also have practical advantages. To create an equivalent soft source from a Condor requires quite a bit of rigging. Most balloons can be set up in an hour or less and moved from one position to another relatively quickly. It is a fairly simple matter to hide the black cable and tag lines, compared to hiding a Condor. They can be controlled from the ground. Tungsten versions can be dimmed, and HMIs on electronic ballasts can be dimmed down to 50%). Balloon lights can afford a more efficient use of the electrician's time.

Balloons are available from various suppliers and individuals. Check out the manufacturers' Web sites (see Appendix F, under Aerial Brilliance, Lights Up, Airstar, Leelium, or LTM).

Specifications for balloon lights are listed on manufacturers' Web sites. Figure 18.4 gives one example of a balloon light's photometrics. The 4.8k HMI (12.5 ft. in diameter) balloon set at a height of 46 ft. provides 20 FC directly below the balloon, which tapers off to 9.8 FC at a 50-ft radius and 2.8 FC at 115 ft from the center. The 16k HMI (16.5 ft. in diameter) balloon set at 82.5 ft. provides 20 FC directly below, 11 FC at a 50-ft. radius, and 2.8 FC at a 200-ft. radius from center.

Tube balloons, which are sausage-shaped, have a lower profile, so they afford the camera a wider shot when the balloons are used on interiors with lower ceilings such as indoor swimming pools, auditoriums, or churches. Vertical dimensions range from 5 to 8½ ft., depending on wattage. Different suppliers have different dimensions. Tube balloons tend to cast the most light out the sides of

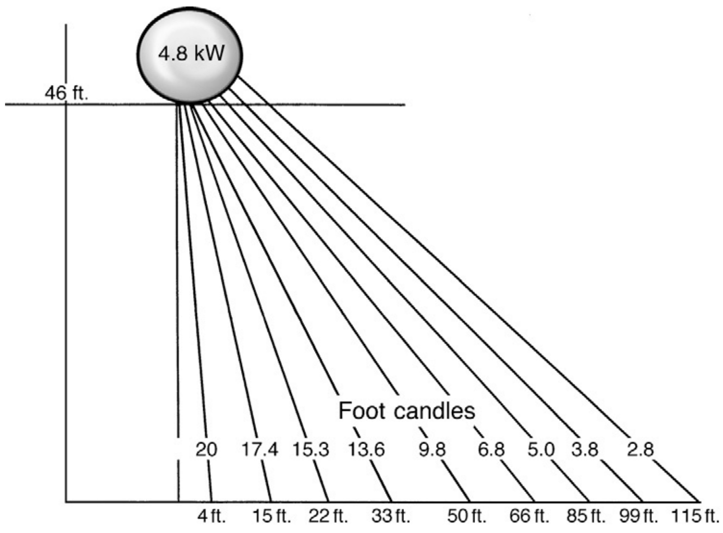

FIGURE 18.4

Sample photometric data for 4.8k HMI lighting balloon.

(Courtesy Lights Up Industries, Los Angeles, CA. Check Web site for current information.)

their long axis, making them ideal for lighting a church aisle, for example. A long aisle might be lit with two or three tube balloons in a line.

Different manufacturers use different materials and design strategies, and some are more successful than others. Some balloons deliver more foot-candles per watt than others by virtue of the envelope material they use. The placement of the globes inside the balloon also affects brightness. Those with the globes hung in the middle of the balloon are generally more efficient than those that light upward from the bottom of the balloon.

The availability of user-friendly accessories also differs from one supplier to another. To give just one example, Lights Up accessories include their Yarmulke polysilk top cover, which cuts top spill. Black-out skirts (designed with snaps and Velcro for quick adjustable application) contain side spill and prevent the walls from being lit on interior sets). Lights Up balloons use black tag lines, which attach with a snap ring or quick link. The black lines are fairly easy to hide and do not have reflective highlights (unlike monofilament lines). Most Lights Up units are available with detachable head cables, so the balloon can be moved easily when working around architectural obstacles. Some balloons are flicker-free or adaptable to flicker-free ballasts (from your own supplier). Some suppliers can provide head cable extensions as necessary.

Most balloon companies send out their equipment with a technician. Experience has shown that sending balloons up and taking them down is a tricky enough operation to warrant having one person single-mindedly dedicated to supervising operations and caring for the balloon.

On the larger balloons, the balloon is attached by its head cable to its road case, which houses the ballasts (HMI units) and winch. Three tag lines are also attached to set the position and height of the balloon. These are tied off to weights, sandbags, or other sturdy tag points. Rigging and stabilization equipment are often required to set the balloon in a difficult spot and prevent the balloon from bobbing and twisting excessively in wind. Lights Up deploys a "wind net" (a netting that wraps over the top of the balloon to help distribute forces evenly around the envelope of the balloon, stabilize it, and prevent unnecessary stresses).

Balloons cannot generally be used in winds greater than 25 mph. They cannot be used if there is lightning in the area. They must be kept well clear of power lines and sharp objects. Also keep them away from sprinkler heads. Balloons can be rained on, although the smaller balloons may not stay afloat if they get too heavy with water. The larger balloons have more lift and can withstand rain and downdrafts better than the smaller balloons. At higher elevations, balloons lose lift and may need to be supported with rigging.

Balloons can be rigged any number of ways, the main concern being not to puncture or overstress the envelope. A balloon can be rested against a ceiling, provided the ceiling is stable and free of sharp edges. Cabling can be draped off to one side or, if necessary, the balloon turned 90° on its side to accommodate running the cables out the side, which helps maximize head room and avoid using tag lines. Balloons can be supported on cable lines run between trees in a forest. They can be flown from a Condor arm for stability. In long term, semipermanent sets on a sound stage, balloons can be filled with air instead of helium and hung upside down from the perms on sound stages. This approach limits their flexibility. Without helium, they become quite heavy. Though air can be used, other gases such as nitrogen are not advisable, because they discolor the envelope and do not have as much lift. Helium is an inert gas—not combustible. In fact, it is a cool gas, which helps ventilate the enclosed lamps.

LIGHTNING EFFECTS

Creating a convincing flash of lightning can be difficult. It requires a very bright, very brief flash that is several stops brighter than the exposure used for the set lighting. To be convincing, it should flicker slightly and vary from flash to flash. For a small area, shutters are sometimes used in front of a fairly large fixture; however, this is a marginally effective technique when used in a large area.

For many years, the brightest, most convincing lightning effect was accomplished with a scissor arc. A scissor arc seems like pure madness today; it consists of a bundle of carbon rods wrapped in wire, fed with large amounts of DC power, and attached to a scissor device that brought the carbons together with the opposite electrode. When the two were brought together, all hell broke loose, and an extremely bright sputtering flash lit up everything within a block. Fragments of hot carbon showered the area around the device, sometimes burning holes right through the blacktop. Needless to say, this approach had some safety issues.

Lightning strikes!

Lightning Strikes! (now part of the Luminys Systems Corp.) developed a line of programmable lightning fixtures that can drench the set in light for up to 3 seconds of continuous light at full intensity, or a sequence of various intensities for up to 8 seconds (Figure 18.5). The unique 1 millisecond response time of the lamp combined with the ability to dim from 100% to 5% allows for rapid changes in intensity to simulate a natural lightning flash or flash from an explosion. The lights are available in a wide range of sizes and features.

FIGURE 18.5

A 250,000 W Lightning Strikes! unit.

(Courtesy Luminys Systems Corp. Lightning Strikes! Los Angeles, CA.)

Luminys Lightning Strikes! Units: Sizes and Features		
Paparazzi head	8k	Small 8k units are commonly used to simulate flash photography
Linear heads	25k, 40k, 70k, 250k, 500k	Up to 3 seconds at full intensity. Up to 8 seconds at varying intensities
Focusable linear heads	40k, 70k, and 250k	Vertical beam spread adjustable between 12° in spot position and 35° full flood
Parabolic reflector heads	8k, 40k, and 200k	Yield greater center beam output per watt than the linear units
Longstrike units	99k, 299k	Can sustain a full power blast of light for up to 10 seconds

Several heads can be connected to a central control unit and fired simultaneously or separately. The color temperature is 5400 K, and the unit is dimmable to about 5% output with no change in color temperature. The units can be very precisely controlled and flash sequences can be programmed, so identical flashes can be repeated in take after take. The units can be ordered fully sealed in waterproof housings for use with rain towers. The 70k head's peak output yields 350 FC at 100 ft with a 45° verticle beam spread, 90° horizontal beam. The smaller lightning units are ideal for interior sets or narrow exterior shots (25 or 40 kW for small sets; 70 kW and larger for large sets and night exteriors).

The Lightning Strikes! controllers and lighting units offer an open field of effects possibilities. Experimenting with different combinations and timing will help you create an optimal effect for your application. For example, for a lightning effect firing two units separately, moments apart, from slightly different directions, and reducing brightness on the second flash enhance a lightning effect, as if the secondary lightning were more distant.

The 40 kW unit can be fitted with a QuickColor system, a specially adapted Wybron color changer and programmable control unit. The color changer provides additional heat protection for the gel scroll. A choice of 10 colors can be selected by DMX512 control. A special handheld control unit comes with the system that provides flash and color control. It can be programmed with up to three-color sequences.

The larger units (250 kW and up) are powerful enough to drench even large expansive sets. They can compete with daylight, so they are ideal for lighting daytime exterior storm scenes. The Longstrike units are a separate product line most commonly used for high-speed cinematography or tabletop applications, but can be used for lighting effects that require long blasts of light. These lights idle at a low level (about 1000 W) and then boost up to full power, 30,000-150,000 W, in 1 millisecond. They are extremely stable and absolutely flicker free up to 1,000,000 frames/s which is often used for scientific or military applications.

Control units

A variety of different control units may be used. For most applications the *undulating controller,* which comes standard with each light, is used to create manual or automatic random lightning flashes.

The *precision fader* is a programmable controller with which one can create, repeat, and loop up and down fades. It is great for creating an explosion effect, for example, with a big initial flash and slow decay, spiked with lesser secondary explosions. Each sequence can last up to 4 seconds, and the unit can hold up to four sequences. The unit comes with four preprogrammed sequences, but you can create custom sequences using a joystick to edit the sequence. Each sequence can change level up to 24 times/second. Machine gun fire flashes can also be created with an on, off, on, off pattern.

The *quad controller* controls up to four lights separately or in unison with eight memory banks that record firing sequences for playback. The quad controller can also be hooked up to a MIDI sequencer running on a laptop computer and triggered from SMPTE time code. The flash sequence is preprogrammed into the MIDI sequencer. During filming, the MIDI sequencer synchronizes to the time code (from a video or audio playback unit), triggering the flashes at exact (repeatable) points in time.

The lights can also be run from a standard DMX512 dimmer console by using an interface box called the *DMX to LS ISO converter*. Brightness level and "mode" are controlled on two adjacent channels and the "mode" pot controls constant slow undulation, medium undulation, or fast undulation. By your assignment of the DMX512 addresses, multiple lights can either be synchronized or operated separately.

An optical or acoustic sensor hidden in the set can also trigger units. A flash camera or a loud noise (gunshot) can be used to trigger the lightning strikes. The duration of strike can be extended from 1 to 36 frames with a choice of intensity level for each frame. Because the Lightning Strikes! flash lasts a minimum of $^1/_{24}$th second, it will be caught on film (whereas a normal strobe flash is about $^1/_{10,000}$th second, which is caught on film only if the shutter of the motion picture camera happens to be open at that instant).

The *16-light sequencer* can chase up to 16 lights at a time. Frames on and off can be preset and repeated. The sequencer can be synchronized to the camera shutter for multiple passes or blue screen work.

Power requirements

Table 18.1 lists specifications for the Lightning Strikes! units as well as power requirements. All units operate on 208-250 V service (single phase, or two legs of a three-phase service), except the 8k and 25k units, which are 120 V AC.

The 70k unit draws about 300 A when fired. Because the time is so short, it can safely be run on 62 A house current. (It is treated like an electric motor starting load.) Although this is a fairly substantial intermittent load, the peak power is within 5% of nominal RMS power, meaning that there is no momentary drain much greater than the nominal power, as there is when striking HMI units, for example.

Running Lightning Strikes! on generators

According to Lightning Strikes!, the generator can be sized as little as almost half the kilowatt output of the fixture. For example, a 70 kW Lightning Strikes! unit can be run off a 40 kW generator (350 A at 120 V AC). Generator companies recommend that, when two 70,000 W heads are used, the plant

Table 18.1 Luminys lightning strikes

Fixture	Number of units	25,000 W	40,000 W	70,000 W	250,000 W	500,000 W
Weight (lbs)		24	30	34	55	63
Head dimensions (in.)		25 × 12 × 9	29 × 12 × 9	32 × 12 × 9	42 × 17 × 11	42 × 19 × 15
Voltage		120 only	208-250 V AC	208-250 V AC	208-250 V AC	208-250 V AC
(Hz)			50/60	50/60	50/60	50/60
Current (momentary) (A)		210	175	300	1050	2100
Power Requirements						
Mains or house (A)	1	40 minimum	40 minimum	63 minimum, 100 optimum	200 minimum, 300 optimum	400 minimum
	2	80	80	125	400	800
	3	120	120	200	600	1200
Generator (kW)	1	24	25	40	180	360
(A)		200 (at 120 V)	200 (at 120 V)	350 (at 120 V)	1500 (at 120 V)	3000 (at 120 V)
	2	42	60	90	360	720
(A)		350 (at 120 V)	500 (at 120 V)	750 (at 120 V)	3000 (at 120 V)	6000 (at 120 V)
	3	60	90	144	540	1.080 MW
(A)		500 (at 120 V)	750 (at 120 V)	1200 (at 120 V)	4500 (at 120 V)	9000 (at 120 V)
Battery pack			Thundervoltz	Thundervoltz	Thundervoltz	Thundervoltz
(W)			40,000	70,000	250,000	500,000
Input required			8 A, 100–250 V AC	10 A, 100–250 V AC	20 A, 100–250 V AC	30 A, 100–250 V AC
Dimensions (in.)			29 × 29 × 26	29 × 29 × 26	2 units each 26 × 24 × 26	2 units each 31 × 32 × 34
Weight (lbs)			425	425	1000	1300

should have at least a 750 A capacity; when three 70,000 W heads are used, the plant should have at least a 1200 A capacity. A sudden heavy load like that of Lightning Strikes! affects all the lights on a generator. They may blink each time the strike hits. To guard against surge current affecting the set lighting, most gaffers order an additional generator to handle the Lightning Strikes! units. If you have to run both on the same generator, use the smaller units (70k or less), keep the bursts short, and have no more than half the amperage capacity of the generator devoted to lightning units.

Thundervoltz battery packs

Alternately, Thundervolts battery pack units eliminate the problem of putting large sudden loads on the generator. All Lightning Strikes! units (except the 25k) can be run off Thundervoltz battery packs. These are specially designed oversized battery-powered packs with an inverter and charger to provide AC specifically for Lightning Strikes! units. The packs deliver power enough to flash the units indefinitely, as long as the AC charger is connected to a power source. The 450-lb Thundervoltz runs two 40k units or a single 70k unit. The 1300-lb double Thundervoltz runs two 250 kW units or a single 500 kW unit. The battery packs are mounted on heavy-duty pneumatic tires.

XENON LIGHTS

Xenon globes have a very short arc length and an extremely bright arc, which makes them easy to collimate into a highly focused beam with very little scatter (Figure 18.6).

The beam is perfectly circular and very narrow. The beam diameter can be controlled with an electronic flood/spot switch on the head and ballast. The intense shaft of daylight-balanced (5600 K) light is sometimes used to simulate sunlight or a searchlight. Xenon fixtures are used in concerts and light shows to create very bright shafts of moving light. Their vibration-resistant design also makes them suitable for use in helicopter and armored tank searchlights.

Strong Britelight and other manufacturers offer a line of high-output xenon lights designed primarily for concert, theatrical, and motion picture use. They are made in various sizes. The smallest, the Maxa Beam, is a powerful 75 W torch-type flashlight that can be powered by a clip-on battery or by 110 V mains. In full spot, the flashlight can deliver 600 FC at a distance of 100 ft. The power supplies for larger units (2000, 4000, 7000, and 10,000 W) may take either 208-230 V single-phase or 208-230 V three-phase, depending on the type. The power supplies provide the startup charge and regulate power to the head. On/off and flood/spot functions can be controlled from the ballast and the head. Xenon lights operate on a pulse DC (equivalent to square-wave current), which allows flicker-free filming at any frame rate up to 10,000 fps.

The lights can be ordered with a normal yoke or a remote-control articulating base and color changer and douser accessories. When operated by a computer-controlled remote, a line of xenon lights can be preprogrammed to perform moving beam effects in unison, or each unit can be controlled separately for different purposes.

Xenon lamps have lamp life of greater than 2000 hours. There is no color shift over the life of the globe, and the color temperature is independent of voltage and current fluctuations. Xenon lamps

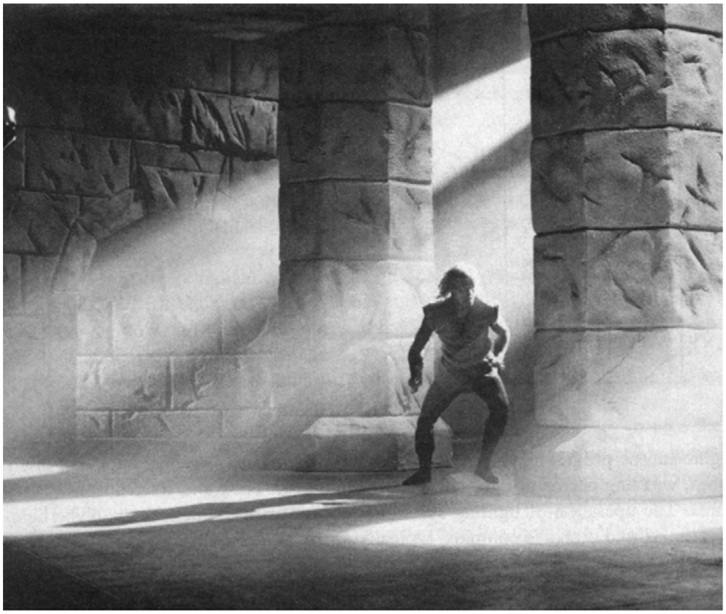

FIGURE 18.6

Xenon lights have a very small arc gap, allowing the beam to be focused into an intense, very narrow shaft.

(Courtesy of Xenotech, Inc., Sun Valley, CA.)

require very careful temperature regulation, and they must use forced-air cooling, which makes them somewhat noisy. Forced-air cooling should continue for at least 5 minutes after the light has been turned off. Also because of cooling requirements Xenons cannot be aimed downward. A mirror accessory must be used to redirect the beam when steep downward angles are required.

During the life of the globe, evaporated tungsten is deposited on the upper inner wall of the envelope and slowly reduces light output (Figure 18.7). The globe should be turned over after half its rated life. These unavoidable deposits are what define the end of a globe's usefulness. Frequent ignition charges accelerate the wear of the electrodes and hasten the darkening of the envelope. Xenon light operators should therefore try to avoid unnecessary shutdowns and startups. If the light is temporarily not needed, pan it into the sky rather than shut it off.

A xenon bulb is always under substantial internal pressure, and the pressure increases when hot. A xenon globe does not break—it explodes. It must always be handled with the utmost care and should never be handled until completely cooled. Bulb manufacturers recommend the use of protective eyewear (or, better, a full-face mask), cotton gloves, and even protective bodywear when handling the globes. For safety reasons, globes should not be operated more than 25% past their rated lifetime. Xenon globes must be installed with proper polarity (Figure 18.7). If operated with improper polarity, the bulb can be rendered useless in a short amount of time.

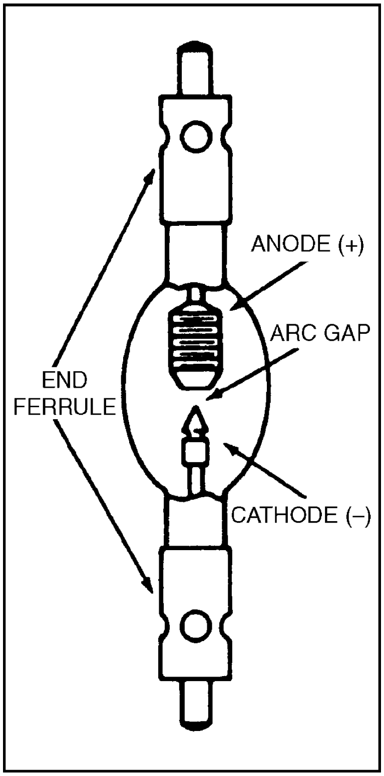

FIGURE 18.7

A xenon globe.

FOLLOW SPOTS

Follow spots, with their powerful long throw, are a staple of music concerts, skating events, award shows, theatrical performances, and circus events (Figure 18.8). Follow spots are typically used as front lights to highlight and set apart the performer from the rest of the stage as they move. Follow spots are also commonly positioned as sidelights or backlights from truss positions. The effect of multiple follow spots tracking a single performer has the kind of splendor that is exciting for an audience.

On a show where the lighting cues are being called over headsets, operating a follow spot is a discipline that requires concentration, ability, and experience. Somewhat like operating a camera, there is a system for feeding the operator the information they need to pick up a performer, there is a protocol that is followed in terms of aesthetics, and the operator is expected to execute their assignment with precision, good judgment, and professionalism. In film and television work,

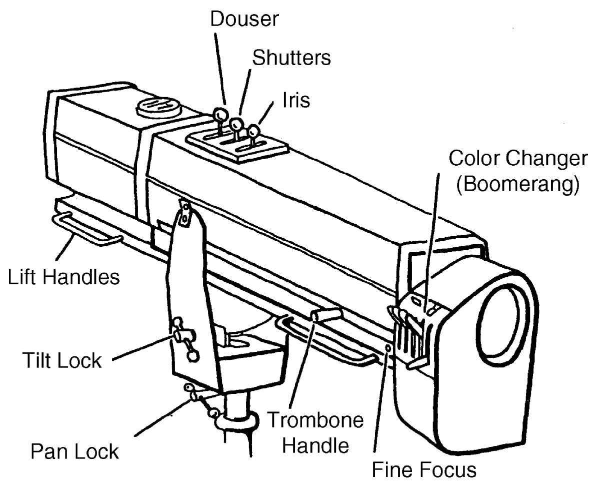

FIGURE 18.8

The Strong Super Trouper follow spot.

(Equipment courtesy of Strong International, Inc., Omaha, NE.)

seasoned follow spot operators will be hired when the show is cued in the tradition of theater and concert lighting. However for an incidental scene in a movie or TV show, it is more than likely the gaffer will call the cues, and any one of the electricians may be assigned to operate the follow spot. This presents a great opportunity to be come practiced at a skill that can broaden your universe of employment contacts into entirely different branches of the entertainment business.

Follow spots are mounted so that the operator may pan and tilt the light smoothly to follow action on the stage. Pan and tilt have brakes to lock the light when unattended. In addition, a follow spot has four primary control adjustments, which the operator uses frequently. Three of the four primary adjustments are made with levers on the top of the light:

Douser: The back knob dowses the entire beam. This is the control used to bring the light up on a performer, and to go to black when the performer exits. It can be used to fade the beam (in a two-count fade, for example) or to snap to black.

Shutters or chopper: The center lever brings horizontal shutters into the top and bottom of the circular pool, creating more of a rectangle. This is often used when the light is covering a group of people to keep the wide beam from spilling off the front of the stage. It is sometimes used instead of the douser to make the light "wink" out.

Iris: The front lever controls the size of the circular pool of light. It does this by cutting the light with an iris. The light level remains unchanged.

Color changer or boomerang: At the front of most follow spots are a group of levers, usually six, that introduce different gel frames into the beam.

The two secondary controls are the *trombone* handle and the *focus* knob.

Trombone: A handle on the side of the light that slides forward or back in a slot. It sets the size and intensity of the beam. This allows a more concentrated, narrow beam for long throws and a

wider, less concentrated beam for shorter throws. The gaffer or lighting designer (LD) will set the brightness level using the trombone.

Focus: The sharpness of the beam edge is adjusted with this knob, typically located near the front of the follow spot. Depending on the application, a sharp beam edge is often desired. Whenever the trombone position is changed, the focus must also the adjusted.

The size and light source type vary with application. In our work, we frequently simply use a Source Four ellipsoidal spotlight as spotlight, however these lack the kinds of controls needed for professional followspot operation (see Chapter 3 for a description of Source Four follow spot retrofits). Small 1k quartz-bulb follow spots, such as the Strong Trouperette, are common for short throws of 30-60 ft (100 FC), such as in a night club or school auditorium. Slightly larger 575 W HMI and 700 W xenon units have throws of 50-160 ft (100 FC). Large follow spots, such as the Strong Super Trouper with a 1k or 2k xenon globe, are used for lighting performers from the back of very large auditoriums and arenas. The Super Trouper has a throw of 130-340 ft (100 FC). The Gladiator and other similar follow spots, using 2500 and 3000 W xenon globes, have throws of up to 460 ft (100 FC).

The larger follow spots typically have a L6-30 (30 A, 240 V twist lock) connector on the power cord. Typical power supplies are 240 V. If 208 V power is being used, a buck and boost transformer can be employed to bring the voltage up. Typically, the ballast is tucked right up against the base of the light. One head feeder is all that is necessary, although a spare is a very good idea.

Preparing the follow spot

As soon as the follow spot operator takes position, he or she will want to set up the light with marks and settings that are needed for the performance. You need to be ready to come out of black, on target, with the correct headroom, and at the right beam size, color, and intensity. If the light has not already been gelled, the operator will want to place new gels in the gel frames. The condition of the gels should be checked every day. A typical gel complement for film and television looks something like this:

Slot 1	Minus green (¼ or ½)
Slot 2	¼ CTO
Slot 3	½ CTO
Slot 4	ND 3
Slot 5	Another ND or a color
Slot 6	Color

If more colors are needed, you can always tape gel over the front of the light. Typically, the CTO will not change, so this is a good one to tape on. The operator should write down which gels are located in which slots and post it on the light so that anyone operating the light will instantly know the color positions. Wrap a small piece of gaffer's tape around the fourth lever of the color changer, so that you can identify the levers by feel in the dark. Count forward or backward from four.

The gaffer meters the light onstage and gives you one or more working intensity settings; mark the settings on the barrel and make sure that the trombone does not slide out of adjustment. The gaffer or LD will read the intensity of the light on stage with a light meter and direct the follow spot operator. With the douser full open, the operator moves the trombone forward for greater intensity (if the LD says “bone-in”) or back for less intensity (“bone-back”). Once a level is set, the operator marks the trombone position (tape usually won’t stick to the side of the hot light, so you can attach it to the front handle, and mark it with a Sharpie). The gaffer may set different trombone settings for upstage, center, and downstage; mark and label each. He or she could also use the neutral density gel to achieve the correct light level.

Once the trombone is set for intensity, the iris is used to size the beam. The operator will set the size of the beam to cover a performer from head to foot. The iris lever position is marked. The operator may also want to mark the iris settings for other sizes too, such as half-body, or a wider group of people.

One of the hardest things to do with consistency is come out of black exactly on target. To accomplish this, professional follow spot operators use a scope or sighting device, such as a Spot Dot, which they attach to the light and carefully align with the beam.

Check to make sure everything is working smoothly. Check all of the controls. Balance of the light so that you are not holding the weight, as this will tire out your arm. Check the pan and tilt. The drag is adjustable. The light should be loose and responsive, not sticky.

Shine the beam on a flat wall and check whether the beam is completely even. If one area is brighter than another, you need to adjust the position of the lamp in the reflector. Sometimes there is a panel that covers the adjustment controls on the back of the light. Figure 18.9 shows lamp adjustment mechanism for a Super Trouper.

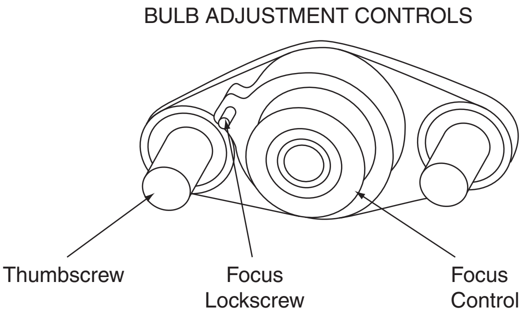

FIGURE 18.9

Two knobs at the back of the fixtures are used to center the lamp and adjust the field evenness. The thumbscrews lock the whole assembly in place. If you loosen them a little, the entire assembly can be moved left right up and down. Center the brightest part of the beam, then tighten the thumbscrews. Then use the focus control to even out the field (release the focus lockscrew before adjusting).

(Courtesy Strong International, Inc., Omaha, NE.)

Operating the follow spot

The follow spot operator stands on the right side of the light within reach of all the controls. Professional follow spot operators equip themselves with long gloves or "arm burners" to protect their left hand and forearm so that they can rest their arm on the top of the light without being burned.

The basic tenants of follow spot operation are as follows. Always keep the performer's face lit; if necessary, lose other parts of the body. Leave adequate headroom (a hand's length above the head is standard). Unless otherwise specified, light the performer from head to foot. Panning and tilting must be smooth and in perfect harmony with the movements of the performer, neither leading them nor lagging, and keeping small movements fluid and subtle so as not to be distracting. Standard sizes you may be asked to cover include: full body, half-body, head and shoulders, or "hold the guitar" (however low that is). When you receive direction to *iris out* from head and shoulders to full body, tilt the light down as you iris out so that the light stays centered on the body. Avoid spilling light onto the apron lip, proscenium, back wall or drops, or other performers. When a group of performers are to be covered with a single light, the beam has to be widened out so much that the top and bottom of the beam start to create unwanted spill problems. In this case, you may be asked to *strip it out*; use the shutter to cut the top and bottom of the beam, again making the beam cover the performers from head to foot.

When follow spots are trained on multiple performers, and they are moving around the stage, at some point it is likely that two lights will overlap. This doubles the light intensity. To avoid this problem, follow spot operators have standard right-of-way rules. The rule is that the downstage performer takes precedence, and the upstage follow spot must douse to half as the two lights overlap. When large numbers of performers are onstage, the stage manager may use a zone defense, which means that each follow spot sticks to a given area and abuts the beam to the next follow spot.

During a performance, a stage manager will be talking to the follow spot operators over a PL system (a belt pack, two-way communications system). You can tape your push-to-talk button to the light's handle so that you don't have the remove your hand from the light to talk. A stage manager will usually give a *warning* of an upcoming pickup and say who is being picked up, where they are entering from, and gel color. This is followed by a *standby* cue, and a *go* cue.

"Warning on a pickup, spot number two, frame three, full body on a man in black, entering down left in one."

"Stand by spot two, frame three on the man."

"Spot two. GO."

Upon receiving a warning, the operator selects the color (frame three in this example), adjusts the iris to the size that will give full body coverage, and swings the light into position using the sight. When he or she gets to the "go" cue, the operator opens the douser and picks up the performer.

Another common command is to *ballyhoo*—this is the classic sweep of light over the stage and the audience in big random figure eights.

The *boomerang* (color changer) typically has six gel frames, which can be introduced into the beam using one of six levers on the end of the barrel. By common convention, the changer levers are numbered from 1 to 6 from front to back. Most changers are designed so that you can roll through the colors; as each new lever is applied, the previous lever automatically releases. You can release all the levers and go to white light by pressing a button underneath the changer levers. If you want to add a color without releasing the previous color, hold your finger over the lever as you engage the new color.

When the spot is not in use on stage, it may be panned off into the ceiling of the arena or into the sky, or it may be doused. Xenon lights should not be turned off unnecessarily, as this drastically

decreases the life of the very expensive xenon bulbs. The douser can be closed for several minutes without causing damage to the light. Do not use the iris or shutter to do this, however, as they will be damaged. Like any xenon light, xenon follow spots use a power supply that converts current to DC. Xenon bulbs are flicker-free at any frame rate and have a daylight color temperature. The bulbs are extremely sensitive to temperature and must be cooled with fans when running. After shutdown, the bulb must be allowed to cool with fans running for at least 5 min. *Never shut down the power before the light has been allowed to cool.*

Xenon lamps are under internal pressure. When hot, the pressure increases to a degree that they can explode if not handled properly. When cool, the lamp may explode if dropped or mishandled. Lamp changes should be made by a qualified person only, wearing proper personal protective equipment including a face shield, clean cotton gloves, and a welder's jacket. The Super Trouper has an adjustment on the ballast for correcting the lamp current. As the lamp ages, this adjustment will need to be changed. The owner's manual specifies the lamp current that should be seen at the lamp housing, and the amount of current that may not be exceeded. Check the manual for details.

Follow spots are designed to be used with colored gels. Despite their candlepower, they should not burn through gel; the optics are arranged so that the beam is least hot as it passes through the gel stage of the barrel. In addition, large follow spots use cooling fans to cool the gel in use. If the gel burns through quickly in one place, it is a sign that the bulb or reflector may be out of alignment. Adjustment knobs on the back of the larger lights are used to align the bulb. If the gel fades quickly, you may want to check to see whether the gel fan is working (if the light is so equipped, the fan is on the underside of the boomerang) and that the air intake is not clogged.

BLACK LIGHTS

Ultraviolet (UV) light or black light occupies a place in the electromagnetic spectrum just below violet, the shortest visible wavelength of light. It is invisible radiant energy. The UV spectrum is subdivided as follows:

UV-A	350-380 nm: black light
UV-B	300-340 nm: used for suntanning
UV-C	200-280 nm: harmful, burns can result

Right around 365 nm, in the middle of the UV-A spectrum, you get maximum transmission for exciting luminescent pigments and materials. When acted on by UV rays, fluorescent and phosphorescent materials are excited to a retroreflective state and emit visible light and vibrant color. Because black light works on some materials and not others, you can create interesting images, such as a disembodied pair of white gloves juggling three glowing orange balls.

Black light fixtures

Black-light blue fluorescent lamps (BLB: 4 ft., 40 W) have little punch; however, when used close up, they can be quite effective. However in a 4-bank, 8-bank, or 10-bank fixture (like a Kino Flo that

has a bright reflector and high-output ballast), fluorescent black lights can make white fabrics and fluorescent colors pop even from a pretty good distance.

Mercury-vapor or metal-halide floodlights ranging from 250 to 400 W are also available from theatrical rental houses. These lamps use a deep-dyed, pot-poured, rolled, or blown glass filter. To create radiant energy at about 365 nm, one needs a light with high-UV output (mercury vapor or metal halide) and a carefully designed UV filter that blocks the visible light (400-700 nm) and the UV-B and UV-C wavelengths.

For lamps larger than 400 W, a UV dichroic coating is necessary to take the extreme heat. Such filters can be used on fixtures up to 18k HMI and xenon lights. Phoebus carries dichroic UV lenses for their xenon lights. Automated Entertainment, in Burbank, developed UV filters for 12k and 18k HMIs and 200, 1200, 2500 W, and 4k SE PARs. Automated also has its own UV and "glow-in-the-dark" pigments and dyes.

Wildfire Inc. is another innovator in this area. It developed a line of UV lights, including a 400 W Fresnel, 400 W floodlight, 400 W ellipsoidal spotlight, and 250 W wide spotlight in a 20°, 50°, or 90° beam diameter. The units operate with ballasts and head feeders like HMIs. Wildfire also offers a wide variety of luminescent materials and paints, including nontoxic dyes, hair spray, lipstick, fabrics, plastics, adhesive tapes, confetti, PVC flexible tubing, and more.

DN Labs is also active in this market, with a line of small lights and specially formulated, highly efficient luminescent rods and sheets that can be machined and won't break.

Photographing with black light

To determine the exposure with black light, take spot meter readings of the luminescent materials to be filmed under the UV lights. To glow vibrantly on film, they should be overexposed by one stop. The effect is less vibrant at exposure and dull one stop under exposure. A UV filter must be used on the camera lens, because the lens cannot focus UV light the same way it can focus the visible spectrum. Without the UV filter, UV produces a hazy softening in the image.

UV light can be combined with conventional light and still create a luminescent effect. The balance depends on how much the effect is to be featured. One could light the scene normally and add UV lights on luminescent materials to give them an extra vibrancy, or a scene could be lit to a lower level with conventional lights so that the luminescent materials stand out. The extreme effect is to black out everything but the luminescent elements. Black makeup eliminates all traces of the performer's skin. With nothing but black light lighting a scene, a woman wearing a luminescent wig and dress, for example, will appear to have no hands or face—only the clothes and hair show up.

Set Lighting Technician's Handbook

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Film Lighting Equipment, Practice, and Electrical Distribution

Fourth Edition

Harry C. Box

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To my mother and father

Preface

TERMINOLOGY

Imagine that your mother visits you on the set. You introduce her to the gaffer, who she says seems like a nice fellow—that is, until he starts giving orders: "Hang a baby. Kill the midget and have two blondes standing by for the martini."

The set lighting profession uses volumes of peculiar-sounding technical terms. In this book, terms are explained the first time they are used and can also be found in the glossary. You will find, however, that the same equipment has different names from country to country, city to city, and studio lot to studio lot. An *obie* light is called a *basher* in England. In Jamaica, a scrim is known as a *strainer*, but here we often simply call it *wire*. A wall sled is called a *Grumpy* at Paramount Studio (the name people around the lot bestowed on its inventor). There are even a few common terms that are difficult to use in polite conversation.

People who work in rental houses will act as if you are out of your mind if you call something by a name different than that with which they are familiar. This can be frustrating when working out of town with a new rental house. Sometimes technicians are far more familiar with the nickname for a piece of gear than they are the proper name. To make matters even more unpredictable, terms change over time and are constantly being invented and evolving. I adopted the terms that, in my experience, are most universally used, but you will no doubt run across many other names that do not appear here.

TWO DECADES OF TRANSITION IN THE LIGHTING INDUSTRY

The practices of lighting technicians in film and television production have undergone many transformations since the summer of 1991, when I first began making notes for what eventually became the first edition of this book. At that time, the conversion from vintage DC distribution equipment to AC was still taking place. Lots of different distribution systems had popped up; there was no dominant standard for connectors and junction boxes. SCR dimmers were suddenly becoming a big part of motion picture lighting for the first time, bringing with them the attendant issues of harmonic currents that overheat transformers. Electronic HMI ballasts were experiencing a troubled adolescence, but were beginning on a path toward greater reliability. At that time there was little or no formal training for lighting technicians. Electricians leaned from each other on the job. For many old-school electricians three-phase AC systems, power factor, current harmonics and even grounding, were new concepts. At that same time, a much larger percentage of production in Los Angeles was non-union. Necessity being the mother of invention, these more thrifty productions spawned many innovative lighting techniques that have since become common practices, but they also often resorted to methods that were actually quite foolhardy and potentially hazardous. One way and another there was a great deal of confusion and misinformation being circulated. It was in this context that I first undertook writing a book for lighting technicians in the film and television industry, with the goal of thoroughly researching the many issues I was aware of, in order to offer lighting technicians an authoritative source of information and guidance.

The forces at work started to spur change in the motion picture industry. There was pressure from electrical inspectors. There was a desire from the manufacturing sector to settle on legal, reliable standards. And there was a realization among employers that sketchy informal training left them open to liability. These forces all began to push the industry in the direction of stricter and more formal rules and guidelines. It was a few years later that the Alliance of Motion Picture and Television Producers (AMPTP) redoubled its efforts to provide proper training for its workforce. Federal OSHA regulations require employers to provide training for certain kinds of work especially those that are potentially hazardous. Up until that point technicians had little or no formal training about safety hazards, yet they were rigging lights to aerial lifts, operating heavy machinery, working in the catwalks high above the stage floor, and connecting up large electrical distribution systems. Contract Services Administration Trust Fund (CSATF) is a nonprofit organization funded by contributions from producers who are signatories of a collective bargaining agreement with the International Alliance of Theatrical and Stage Employees (IATSE) (based on hours worked by covered employees). CSATF is administered by a board of trustees appointed by the Alliance of Motion Picture and Television Producers (AMPTP). This is how producers have arranged to provide training to an essentially freelance workforce in order to meet OSHA requirements and create a safer work environment. The second edition of this book was formally adopted by Local 728 (Hollywood Set Lighting) as part of that effort.

In the past ten years Contract Services has vastly expanded and improved their Safety Training program to include the Safety Pass program, required for all employees, and it also partially funds Local 728's voluntary Skills Training program. This edition of the Set Lighting Technician's Handbook is designed to be a primer and a reference for some of the topics covered in the training program.

This book has existed in a time frame spanning a massive shift toward greater awareness and education for lighting technicians. To some extent, it has been a part of that shift. In this edition you will find a great many changes to the book, which are a result of the formalization of training and rethinking of safety that has occurred in the last decade. Practices that were once casually accepted are now carefully controlled. Things like using flammable materials or non-UL-listed parts and equipment, procedures for tying-in to electrical panels, use of electricity around water and in damp locations: these are just a few of the areas where training and formalization of practices (not to mention the efforts of equipment manufacturers to bring us new solutions) has greatly improved the safety of our daily work. Woven throughout this edition are the latest guidelines of many different safety and regulatory organizations, including: the National Electrical Code, OSHA, Fire and Building Codes, studio safety departments, the CSATF Safety Pass Training and Safety Bulletins, ESTA recommendations for safe practices and standards, as well as the safety recommendations of equipment manufacturers. To the extent possible, I have sought to make sure that the practices discussed here are all fully compliant with current standards and training.

Acknowledgments

The fourth edition of the *Set Lighting Technician's Handbook* marks a big step forward. In writing this edition, I was very fortunate to have the support of many top professionals in production as well as distinguished experts in the manufacturing sector. The insights and perspective they offered made it possible for me to write a well-rounded book about many exciting technologies. I am very grateful to Mike Bauman for his kind input and terrific photographs. In recent years, Mike has blazed a path embracing some of the most technologically advanced lighting solutions. I owe a debt of thanks to Richard Cadena, Scott Barnes, Josh Thatcher, Jeff Levi, and John Amorelli for their input on the subject of lighting control technology and moving lights. Thanks to Mike Wood (Mike Wood Consulting), Rob Gerlach (Selador/ETC), Ryan Fletcher (ARRI), David Amphlett (Gekko), Jim Sanfilippo (NILA), Richard Lund (Philips), and Lee Ford Parker (JiffyFX.com) for their valuable contributions to the new chapter on LEDs. Thanks to the terrific team at ARRI Lighting—John Gresch, Mike Jones, Aeron Weller, and An Tran—for their continuing support, and contributions especially in regard to HMI troubleshooting. The dazzling cover photo of this edition is by An Tran. Other experts in the field helped shape this new edition: Steve Terry (ETC), Michael Lay (Strand) lent their expertise on dimming; Bob Cookson (Illumination Dynamics) Russle Saunders (Saunders Generators) and Ron Dahlquist (Dadco) on transformers and generators; John Parkinson (Power To Light), Paul Tipple and Phil Ellems (Power Gems) on HMI electronic ballasts; Stewart Lennox (battery packs) and Guy Holt on small generators; Michael Skinner on entertainment industry applications of the National Electrical Code; Andy C. Huber on underwater lighting; and my old friend and colleague Brian O'Kelley lent an AD's perspective to the opening chapter. Other lighting professionals who contributed include Erik Messerschmitt, Mike Ambrose, Dave Devlin, Dwight Campbell, Martin Weeks, and many others. My thanks to the Local 728 Safety Training Program and Contract Services, especially Allan Rowe, whose comprehensive work developing Skills Training courses for Local 728 plays no small part in helping the membership remain the best trained, most experienced lighting technicians in the world. My sincere thanks to the many individuals who gave me feedback and suggestions for this edition: Daniel Aleksic, David E. Elkins, John Gates, Michael Hofstein, Seth Jason, and Stephen Lighthill.

I gratefully acknowledge the many manufacturers who provided technical information, photographs, and illustrations. The manufacturers are listed in Appendix F.

This book was first published in 1993. I am deeply indebted to many individuals for their generous contributions to this book over the years: Darryl Murchison, whose discussions during the early stages of writing the first edition helped set the book on course; Doug Pentek, Earl Gilbert, Larry Parker, Cyrus Yavneh, Russ Brandt, Dean Bray, Frieder Hochheim, Herb Breitling, Michael Kaiping, Scott Toland, and Jon Bart, all of whom read and improved sections of the book in its first and second editions; Richard Mula and Pete Romano, who shed much light on the subject of underwater lighting; Frank "the Dinosaur" Valdez and Gary Scalzo, who lent their expertise to the section on rigging; and Vance Trussell, whose suggestions and ongoing interest and encouragement were invaluable to me. My thanks to Eric King, who shared his expertise on HMIs and electronic ballasts. My thanks to Bernie Kret at Strand, who helped upgrade the section on electronic dimmers for the second edition. I owe a debt of gratitude to Chris Barratt, without whose generosity and vast

experience I could not have created the new section on generator troubleshooting, and whose legacy lives on despite his passing.

A special note of thanks to the illustrators, Shawn Murphy and Lisa Cyr, who created the hand-drawn illustrations for the first edition and who may well have been inking drawings on their wedding night to make the publication deadline. Praise also goes to the talents of John Huey, who created additional artwork for the second edition. For new illustrations in the third edition, I thank Dan Haberkorn. Thanks to my dear friend and colleague Mark Doering-Powell for his advice and artwork in the section on blue-screen photography. Thanks to Laura Mancini for modeling for the book, and to Keith Morgan, for lending a hand (and a couple of very nice lights). My thanks also to Doug Pentec and Carly Barber of Hollywood Rental and Robert Guzman of Concept Lighting for the use of their rental equipment in creating the artwork in the first edition, and Debra at Cineworks for use of equipment for artwork added in the third edition.

More than ever, I am grateful to the team at Focal Press—my editor Michele Cronin, Elinor Actipis, and Marie Lee, whose help, support, and buoyant optimism helped me see this through.

I am thankful, once again, to Joan Box, my faithful and talented (unofficial) copyeditor who has taken an interest in my writing since I was first able to form letters. It is a true testament to a mother's love that she endures all this techno mumbo-jumbo, but it is always a joy to work together on it.

Big, big, ginormous thanks, finally, to my loving wife Stacey, who is officially completely sick of this book at this point, and with good reason. Thank you for your patience and support. I love you with all my heart.

APPENDIX

Photometric calculations and tables A

A listing of photometric data about many different lights can be found on the *Set Lighting Technician's Handbook* Web site. These tables list lots of information that may be needed such as lamp designation, weight, and scrim size, as well as beam angle and candle power. Beam angle data allows you to calculate the beam diameter of a light at any distance you choose. Knowing the candle power allows you to calculate foot-candle intensity at any distance.

Some manufacturers provide photometric calculators on their Web sites. ARRI Lighting's Web site features a very nice calculator program.

CONVERTING TO FOOT-CANDLES

Use Table A.1 to figure out about how many foot-candles you need to achieve a desired f-stop. The ISO of the film may be that recommended by Kodak or Fuji or it may be adjusted to account for exposure differences due to filters, frame rates, and intentional over- or underexposure.

CALCULATING FIELD DIAMETER

If you want to know how much area a beam of light covers at a particular distance, see Table B.2. You can find the beam angle for many lights on manufacturers as well as in the Lamp Specification tables on the *Set Lighting Technician's Handbook* Web site.

For ellipsoidal fixtures, manufacturers often list a "multiplier" to use to find field diameter. Table A.2 lists specifications for various commonly used ellipsoidals. Included in this table (and in any manufacturer's catalog) is the multiplier used to calculate field diameter at a given throw. For example, the Source Four 36° fixture has a multiplier of 0.65. If the throw is 20 ft., we can calculate the field diameter:

$$\text{distance} \times \text{multiplier} = \text{field diameter}$$

$$20\text{ ft.} \times 0.65 = 13\text{ ft.}$$

CALCULATING INTENSITY

To get a rough idea of how much light you get from a given fixture at a given distance, you can look up the candle-power (cd) of almost any light fixture on the manufacturer's Web site or the Lamp Specification tables on the *Set Lighting Technician's Handbook* Web site. Plug this number into Table A.3 to find the approximate reading in foot-candles. Then use Table A.1 to find the

corresponding f-stop. Note that manufacturers' photometric data are based on optimal performance. Your situation on the set is never optimal. Many everyday factors conspire to reduce the performance of a fixture: the age of a bulb, dirt on the lens and reflector, suboptimal voltage, smoke or dirt in the air, and so forth. Needless to say, your results may vary.

We can calculate the intensity of a light at any distance using the inverse square law. To find the amount of light, divide the source candle power given in candela (cd) by the distance squared:

$$\frac{\text{Source(cd)}}{D^2(\text{ft})} = \text{fc}, \quad \text{or} \quad \frac{\text{Source(cd)}}{D^2(\text{m})} = \text{lux}$$

Or use Table B.3 to ascertain the light level of any fixture at any distance. For example, a Source Four 36° fixture has a source intensity of 84,929 cd. The intensity at 20 ft. is therefore:

$$\frac{84,929}{(20)^2} = 212 \text{ FC}$$

You can use this equation to calculate the source intensity (cd) of a given fixture by measuring the FC level at a given distance or to calculate the distance necessary to achieve a particular FC level from a given fixture:

$$\text{cd} = \text{FC} \times D^2, \text{ where } D = \frac{\text{fixture intensity(cd)}}{\text{light level(FC)}}$$

Table A.1 f-Stop Versus Foot-Candles for Various Film Speeds

ISO	*f*/1.0	*f*/1.4	*f*/2	*f*/2.8	*f*/4	*f*/5.6	*f*/8	*f*/11	*f*/16	*f*/22
10	120	250	500	1000	2000	4000	8000	16,000	32,000	64,000
12	100	200	400	800	1600	3200	6400	12,800	25,000	50,000
16	80	160	320	640	1250	2500	5000	10,000	20,000	40,000
20	64	125	250	500	1000	2000	4000	8000	16,000	32,000
25	50	100	200	400	800	1600	3200	6400	12,800	25,000
32	40	80	160	320	640	1250	2500	5000	10,000	20,000
40	32	64	125	250	500	1000	2000	4000	8000	16,000
50	25	50	100	200	400	800	1600	3200	6400	12,800
64	20	40	80	160	320	640	1250	2500	5000	10,000
80	16	32	64	125	250	500	1000	2000	4000	8000
100	12	25	50	100	200	400	800	1600	3200	6400
125	10	20	40	80	160	320	640	1250	2500	5000
160	8	16	32	64	125	250	500	1000	2000	4000
200	6.4	13	25	50	100	200	400	800	1600	3200
250	5	10	20	40	80	160	320	640	1250	2500
320	4	8	16	32	64	125	250	500	1000	2000
400	3.2	6.4	13	25	50	100	200	400	800	1600
500	2.5	5	10	20	40	80	160	320	640	1280
640	2	4	8	16	32	64	120	240	500	1000
800	1.6	3.2	6.4	12	24	50	100	200	400	800
1000	1.2	2.5	5	10	20	40	80	160	320	640

Notes: *Incident light in foot-candles. Frame rate: 24 fps. Exposure time:* $^{1}/_{50}$s *(180° shutter opening).*

Table A.2 Beam Diameter (in ft.) at Various Distances

Beam Angle (°)	Multiplier	Distance (ft.)												
		5	10	15	20	25	30	40	50	75	100	150	200	250
2	0.03	0.2	0.3	0.5	0.7	0.9	1.0	1.4	1.7	2.6	3.5	5.2	7.0	8.7
4	0.07	0.3	0.7	1.0	1.4	1.7	2.1	2.8	3.5	5.2	7.0	10.5	14.0	17.5
6	0.10	0.5	1.0	1.6	2.1	2.6	3.1	4.2	5.2	7.9	10.5	15.7	21.0	26.2
8	0.14	0.7	1.4	2.1	2.8	3.5	4.2	5.6	7.0	10.5	14.0	21.0	28.0	35.0
10	0.17	0.9	1.7	2.6	3.5	4.4	5.2	7.0	8.7	13.1	17.5	26.2	35.0	43.7
12	0.21	1.1	2.1	3.2	4.2	5.3	6.3	8.4	10.5	15.8	21.0	31.5	42.0	52.6
14	0.25	1.2	2.5	3.7	4.9	6.1	7.4	9.8	12.3	18.4	24.6	36.8	49.1	61.4
16	0.28	1.4	2.8	4.2	5.6	7.0	8.4	11.2	14.1	21.1	28.1	42.2	56.2	70.3
18	0.32	1.6	3.2	4.8	6.3	7.9	9.5	12.7	15.8	23.8	31.7	47.5	63.4	79.2
20	0.35	1.8	3.5	5.3	7.1	8.8	10.6	14.1	17.6	26.4	35.3	52.9	70.5	88.2
22	0.39	1.9	3.9	5.8	7.8	9.7	11.7	15.6	19.4	29.2	38.9	58.3	77.8	97.2
24	0.43	2.1	4.3	6.4	8.5	10.6	12.8	17.0	21.3	31.9	42.5	63.8	85.0	106.3
26	0.46	2.3	4.6	6.9	9.2	11.5	13.9	18.5	23.1	34.6	46.2	69.3	92.3	115.4
28	0.50	2.5	5.0	7.5	10.0	12.5	15.0	19.9	24.9	37.4	49.9	74.8	99.7	124.7
30	0.54	2.7	5.4	8.0	10.7	13.4	16.1	21.4	26.8	40.2	53.6	80.4	107.2	134.0
32	0.57	2.9	5.7	8.6	11.5	14.3	17.2	22.9	28.7	43.0	57.3	86.0	114.7	143.4
34	0.61	3.1	6.1	9.2	12.2	15.3	18.3	24.5	30.6	45.9	61.1	91.7	122.3	152.9
36	0.65	3.2	6.5	9.7	13.0	16.2	19.5	26.0	32.5	48.7	65.0	97.5	130.0	162.5
38	0.69	3.4	6.9	10.3	13.8	17.2	20.7	27.5	34.4	51.6	68.9	103.3	137.7	172.2
40	0.73	3.6	7.3	10.9	14.6	18.2	21.8	29.1	36.4	54.6	72.8	109.2	145.6	182.0
42	0.77	3.8	7.7	11.5	15.4	19.2	23.0	30.7	38.4	57.6	76.8	115.2	153.5	191.9
44	0.81	4.0	8.1	12.1	16.2	20.2	24.2	32.3	40.4	60.6	80.8	121.2	161.6	202.0
46	0.85	4.2	8.5	12.7	17.0	21.2	25.5	34.0	42.4	63.7	84.9	127.3	169.8	212.2
48	0.89	4.5	8.9	13.4	17.8	22.3	26.7	35.6	44.5	66.8	89.0	133.6	178.1	222.6
50	0.93	4.7	9.3	14.0	18.7	23.3	28.0	37.3	46.6	69.9	93.3	139.9	186.5	233.2
52	0.98	4.9	9.8	14.6	19.5	24.4	29.3	39.0	48.8	73.2	97.5	146.3	195.1	243.9
54	1.02	5.1	10.2	15.3	20.4	25.5	30.6	40.8	51.0	76.4	101.9	152.9	203.8	254.8
56	1.06	5.3	10.6	16.0	21.3	26.6	31.9	42.5	53.2	79.8	106.3	159.5	212.7	265.9
58	1.11	5.5	11.1	16.6	22.2	27.7	33.3	44.3	55.4	83.1	110.9	166.3	221.7	277.2
60	1.15	5.8	11.5	17.3	23.1	28.9	34.6	46.2	57.7	86.6	115.5	173.2	230.9	288.7
62	1.20	6.0	12.0	18.0	24.0	30.0	36.1	48.1	60.1	90.1	120.2	180.3	240.3	300.4
64	1.25	6.2	12.5	18.7	25.0	31.2	37.5	50.0	62.5	93.7	125.0	187.5	249.9	312.4
66	1.30	6.5	13.0	19.5	26.0	32.5	39.0	52.0	64.9	97.4	129.9	194.8	259.8	324.7
68	1.35	6.7	13.5	20.2	27.0	33.7	40.5	54.0	67.5	101.2	134.9	202.4	269.8	337.3
70	1.40	7.0	14.0	21.0	28.0	35.0	42.0	56.0	70.0	105.0	140.0	210.1	280.1	350.1
72	1.45	7.3	14.5	21.8	29.1	36.3	43.6	58.1	72.7	109.0	145.3	218.0	290.6	363.3
74	1.51	7.5	15.1	22.6	30.1	37.7	45.2	60.3	75.4	113.0	150.7	226.1	301.4	376.8
76	1.56	7.8	15.6	23.4	31.3	39.1	46.9	62.5	78.1	117.2	156.3	234.4	312.5	390.6
78	1.62	8.1	16.2	24.3	32.4	40.5	48.6	64.8	81.0	121.5	162.0	242.9	323.9	404.9
80	1.68	8.4	16.8	25.2	33.6	42.0	50.3	67.1	83.9	125.9	167.8	251.7	335.6	419.5
82	1.74	8.7	17.4	26.1	34.8	43.5	52.2	69.5	86.9	130.4	173.9	260.8	347.7	434.6
84	1.80	9.0	18.0	27.0	36.0	45.0	54.0	72.0	90.0	135.1	180.1	270.1	360.2	450.2

Note*: Multiply distance times multiplier to get diameter at any distance.*

Table A.3 Brightness in Foot-Candles of Fixtures at Various Distances (Each Shaded Area Represents a Range of ⅓ of an f-Stop)

						Distance (ft)									
Fixture	**Modifiers**	**Candella**	**Output**	**f-Stop (250 ASA $\frac{1}{50}$ s) at 20 ft.**	**f-Stop (250 ASA $\frac{1}{50}$ s) at 80 ft.**	**2**	**3**	**5**	**10**	**15**	**20**	**25**	**30**	**40**	**50**
		938		f-0.7		235	104	38	9	4	2	2	1	1	0
		1250				313	139	50	13	6	3	2	1	1	1
200 W Joker-Bug	w/Chimera		1300												
Kino-Flo Diva-Lite 200			1500												
		1600				400	178	64	16	7	4	3	2	1	1
Kino-Flo 2-ft. 4-bank	w/o Louvre		1800												
		1875		f-1		469	208	75	19	8	5	3	2	1	1
100 W Pepper	Flood		2300												
Kino-Flo 2-ft. 2-bank	w/o Louvre		2100												
100 W Dedo	Flood		2147												
		2500		f-⅓		625	278	100	25	11	6	4	3	2	1
Kino-Flo 4-ft. 2-bank	w/o Louvre		2700												
Kino-Flo Diva-Lite 400			3000												
		3200		f-1⅔		800	356	128	32	14	8	5	4	2	1
750 Zip															
400 W Joker-Bug	SW w/Chimera		3200												
150 W Dedo	Flood, 3400 K		3483												
Kino-Flo 4-ft. 4-bank	w/o Louvre		3500												
		3750		f-1.4		938	417	150	38	17	9	6	4	2	2
200W Pepper	Flood		3900												
		5000		f-1.4⅓		1250	556	200	50	22	13	8	6	3	2
1k Soft															
100 W Pepper	Spot		5500												
300 W Pepper	Flood		4600												
Kino-Flo Flathead 80	w/o Louvre		6000												
420 W Pepper	Flood		6100												
		6400		f-1.4⅔		1600	711	256	64	28	16	10	7	4	3
200 W HMI fresnel	Flood														
		7500				1875	833	300	75	33	19	12	8	5	3

						Distance (ft.)									
						3	5	10	15	20	25	30	40	50	60
		7500		f-2		833	300	75	33	19	12	8	5	3	2
650 W Fresnel	Flood														
Kino-Flo Wall-O-Lite	w/o Louvre		7500												
400 W Dedo 436	Flood		7614												
650 W Dedo 650	Flood		8100												
200 W Joker-Bug	SW		9000												
		10,000		f-2⅓		1111	400	100	44	25	16	11	6	4	3
2k Soft															
200 W Pepper	Spot		10,500												
650 W Pepper	Flood		11,000												
200 W Joker-Bug	FF		11,700												
400 W Dedo 400D	Flood		11,907												
		12,500		f-2⅔		1389	500	125	56	31	20	14	8	5	3
Kino-Flo Blanket Light			13,700												
400 W Joker-Bug	FF		14,400												
		15,000		f-2.8		1667	600	150	67	38	24	17	9	6	4
4k Soft															
1k Baby Fresnel	Flood														
1k Mickey Mole	Flood														
400 W Joker-Bug	SWF		18,800												
		20,000		f-2.8⅓		2222	800	200	89	50	32	22	13	8	6
575 W HMI Fresnel	Flood														
		25,000		f-2.8⅔			1000	250	111	63	40	28	16	10	7
300 W Pepper	Spot		27,500												
3.3k SoftSun	Flood		27,500												
200 W Joker-Bug	W		30,200												
		30,000		f-4	f-1		1200	300	133	75	48	33	19	12	8
2k Mighty Mole	Flood														
800 W Joker-Bug	FF		38,800												
		40,000		f-4⅓			1600	400	178	100	64	44	25	16	11
8k Soft															
420 W Pepper	Spot		44,400												
400 W Joker-Bug	WF		44,400												
2k Blonde or Arrilight	Flood														
1k PAR 64	WF														
		50,000		f-4⅔			2000	500	222	125	80	56	31	20	14
2k 8″ Junior Fresnel	Flood														
100 W Dedo	Spot		50,220												
650 W Pepper	Spot		52,800												
3.3k SoftSun	Spot		55,000												
		60,000		f-5.6	f-1.4		2400	600	267	150	96	67	38	24	17

						Distance (ft.)										
						5	**10**	**15**	**20**	**25**	**30**	**40**	**50**	**60**	**70**	**80**
		60,000		f-5.6	f-1.4	2400	600	267	150	96	67	38	24	17	12	9
1200 W HMI Fresnel	Flood															
150 W Dedo	Spot															
	3400 K		62,700													
		80,000		f-5.6⅓		3200	800	356	200	128	89	50	32	22	16	13
5k Baby Senior																
Fresnel	Flood															
200 W Joker-Bug	M		96,800													
		100,000		f-5.6⅔		4000	1000	444	250	160	111	63	40	28	20	16
1200 W HMI PAR	SWF															
650 W Dedo 650	Spot		115,843													
		120,000		f-8	f-2	4800	1200	533	300	192	133	75	48	33	24	19
10k Baby Tenner	Flood															
400 W Dedo 436	Spot		120,366													
1k Mickey Mole	Spot															
400 W Joker-Bug	M		152,000													
2500 W HMI Fresnel	Flood															
2500 W HMI Par	SWF															
1k PAR 64	MF															
		160,000		f-8⅓		6400	1600	711	400	256	178	100	64	44	33	25
4k HMI Fresnel	Flood															
1200 W HMI PAR	WF															
800 W Joker-Bug	SWF Frosted		181,000													
4k HMI SE Par	Fres															
2k Mighty Mole	spot															
		200,000		f-8⅔		8000	2000	889	500	320	222	125	80	56	41	31
2500 W HMI SE Par	WF															
400 W Dedo 400D	Spot		201,852													
		240,000		f-11	f-2.8	9600	2400	1067	600	384	267	150	96	67	49	38
4k HMI SE Par	SWF															
800 W Joker-Bug	MF		315,000													
		320,000		f-11⅓		12,800	3200	1422	800	512	356	200	128	89	65	50
6k HMI Fresnel	Flood															
	Frosted															
6k SE HMI Par	Fres															
1k PAR 64	NSP															
6k Par LTM	FF		380,000													
		400,000		f-11⅔		16,000	4000	1778	1000	640	444	250	160	111	82	63
20k Fresnel	Flood															
		480,000		f-16	f-4	19,200	4800	2133	1200	768	533	300	192	133	98	75

						Distance (ft.)									
						10	**15**	**20**	**25**	**30**	**40**	**50**	**60**	**80**	**100**
		480,000		f-16	f-4	4800	2133	1200	768	533	300	192	133	75	48
12k HMI Fresnel	Flood														
200 W Joker-Bug	S		591,800												
4k HMI SE Par	WF														
1k PAR 64	VNSP														
		640,000		f-16⅓		6400	2844	1600	1024	711	400	256	178	100	64
18k HMI Fresnel	Flood														
12k Par LTM	FF		660,000												
6k Par LTM	SWF		730,000												
		800,000		f-16⅔		8000	3556	2000	1280	889	500	320	222	125	80
1200 W HMI Par	MF														
2500 W HMI SE Par	MF														
		960,000		f-22	f-5.6	9600	4267	2400	1536	1067	600	384	267	150	96
4k HMI SE Par	MF														
50k SoftSun	Flood		1,050,000												
12k Par LTM	SWF		1,090,000												
6k Par LTM	W		1,260,000												
		1,280,000		f-22⅓		12,800	5689	3200	2048	1422	800	512	356	200	128
1200 W HMI PAR	NSP														
400 W Joker-Bug	NSP		1,544,000												
		1,600,000		f-22⅔		16,000	7111	4000	2560	1778	1000	640	444	250	160
12k Par LTM	W		1,790,000												
		1,920,000		f-32	f-8	19,200	8533	4800	3072	2133	1200	768	533	300	192
1200 W HMI par	VNSP														
50k SoftSun	Spot		2,375,000												
800 W Joker-Bug	NSP		2,094,000												
6k Par LTM	M		2,480,000												
		2,560,000		f-32⅓		25,600	11,378	6400	4096	2844	1600	1024	711	400	256
2500 W HMI SE par	NSP														
		3,200,000		f-32⅔		32,000	14,222	8000	5120	3556	2000	1280	889	500	320
12k Par LTM	M		3,600,000												
		3,840,000		f-44	f-11	38,400	17,067	9600	6144	4267	2400	1536	1067	600	384

						Distance (ft.)									
						15	**20**	**25**	**30**	**40**	**50**	**60**	**80**	**100**	**150**
		3,840,000		f-44	f-11	17,067	9600	6144	4267	2400	1536	1067	600	384	171
		5,120,000		f-44⅓		22,756	12,800	8192	5689	3200	2048	1422	800	512	228
2500 W HMI SE Par	VNSP														
		6,400,000		f-44⅔		28,444	16,000	10,240	7111	4000	2560	1778	1000	640	284
		7,680,000		f-64	f-16	34,133	19,200	12,288	8533	4800	3072	2133	1200	768	341
12k HMI Fresnel	Spot														
		10,240,000		f-64⅓		45,511	25,600	16,384	11,378	6400	4096	2844	1600	1024	455
4k HMI SE PAR	VNSP														
		12,800,000		f-64⅔		56,889	32,000	20,480	14,222	8000	5120	3556	2000	1280	569
6k HMI SE Par LTM	S		17,120,000												
		15,360,000		f-88	f-22	68,267	38,400	24,576	17,067	9600	6144	4267	2400	1536	683
12k Par LTM	S		19,680,000												
		20,480,000		f-88⅓		91,022	51,200	32,768	22,756	12,800	8192	5689	3200	2048	910

Direct sun, 11 a.m., clear day, January, in Los Angeles = 8400 FC.

APPENDIX

Lamp Tables

B

Table B.1 Photo Floods, Mushroom Floods, MR-16s: Medium Screw Base Lamps

Type	Lamp and Base Type	Volts	Watts	Kelvin Color	Life (h)
Standard and Pear-Shaped (PS) Photofloods					
PH-211	A-21 Medium	120	75	3200	100
PH-212	A-21 Medium	120	150	3050	100
PH-213	A-21 Medium	120	250	3400	3
BBA (No 1)	A-21 Medium	120	250	3400	3
BCA (B-1)	A-21 Medium	120	250	4800	3
ECA	A-23 Medium	120	250	3200	20
BAH	A-21 Medium	120	300	3200	20
EBV (No 2)	PS-25 Medium	120	500	3400	6
EBW (B-2)	PS-25 Medium	120	500	4800	6
ECT	PS25/5 Medium	120	500	3200	60
Mushroom Lamps					
DAN (R-20)	R-20 Meduim	118	200	3400	4
BEP (R-30)	R-30 Medium	118	300	3400	4
EBR (R-30)	R-30 Medium	118	375	3400	4
DXH (PH/RFL-2)	R-40 Medium	118	375	3200	15
BFA (R-34)	R-40 Medium	118	375	3400	4
DXC (PH/RFL-2)	R-40 Medium	118	500	3400	6
EAL	R-40 Medium	120	500	3300	15
FAE	R-40 Medium	118	550	3400	10
MR-16 Lamps Medium Screw Base					
FSA (NSP) or JDR120V75W NSP	MR-16, Medium	120	75	3000	–
FSB (MFL) or JDR120V75W MFL	MR-16, Medium	120	75	3000	–
FSD (WFL) or JDR120V75W WFL	MR-16, Medium	120	75	3000	–
FSC (NSP) or JDR120V100W NSP	MR-16, Medium	120	100	3000	–

Continued

Table B.1 Photo Floods, Mushroom Floods, MR-16s: Medium Screw Base Lamps—cont'd.

Type	Lamp and Base Type	Volts	Watts	Kelvin Color	Life (h)
FSE (MFL) or JDR120V75W MFL	MR-16, Medium	120	100	3000	–
FSF (WFL) or JDR120V75W WFL	MR-16, Medium	120	100	3000	–

The lamp type designation indicates type and size (in eighths of inches). For example, R-40 indicates a reflector lamp with a 5-in. diameter (40/8 = 5). An R-30 lamp is 3-$\frac{6}{8}$ in. diameter, an MR-16 is 2 in. diameter, and so on.
The mushroom floods listed here are all 3000 K or more. Mushroom floods also come in a wide variety of wattages that have lower color temperature, flood, and spot. R-40s, for example, come in 75, 150, and 300 W.
The MR-16s listed are 120 V medium screw base. MR-16 and MR-11 lamps also come in a wide variety of other configurations. The 6 and 12 V versions with a small two-pin base are the most common type.

Table B.2 Fluorescent Lamps

Watts	Lamp	Diameter	Length	Description	Kelvin	Base
KF55 (Daylight) Lamps						
6	T5	$\frac{5}{8}''$	9″	F6T5/KF55	5500	Mini Bipin
14	T12	1-$\frac{1}{2}''$	15″	FI4T12/KF55 SFC	5500	Med. Bipin
20	T12	1-$\frac{1}{2}''$	24″	F20T12/KF55 SFC	5500	5500
30	T12	1-$\frac{1}{2}''$	36″	F30T12/KF55 SFC	5500	5500
40	T12	1-$\frac{1}{2}''$	48″	F40T12/KF5S SFC	5500	5500
55	T12	1-$\frac{1}{2}''$	72″	F72T12/KF55/SL SFC	5500	Single Pin
85	T12	1-$\frac{1}{2}''$	72″	F72T12/KF55/HO SFC	5500	Med. Bipin
75	T12	1-$\frac{1}{2}''$	96″	F96T12/KF55/SL SFC	5500	Single Pin
110	T12	1-$\frac{1}{2}''$	96″	F96T12/KF55/HO SFC	5500	Med. Bipin
KF32 (Tungsten) Lamps						
6	T5	$\frac{5}{8}''$	9″	F6T5/KF32	3200	Mini Bipin
14	T12	1-$\frac{1}{2}''$	15″	F14T12/KF32 SFC	3200	Med. Bipin
20	T12	1-$\frac{1}{2}''$	24″	F20T12/KF32 SFC	3200	Med. Bipin
30	T12	1-$\frac{1}{2}''$	36″	F30T12/KF32 SFC	3200	Med. Bipin
40	T12	1-$\frac{1}{2}''$	48″	F40T12/KF32 SFC	3200	Med. Bipin
55	T12	1-$\frac{1}{2}''$	72″	F72T12/KF32/SL SFC	3200	Single Pin
85	T12	1-$\frac{1}{2}''$	72″	F72T12/KF32/HO SFC	3200	Med. Bipin
75	T12	1-$\frac{1}{2}''$	96″	F96T12/KF32/SL SFC	3200	Single Pin
110	T12	1-$\frac{1}{2}''$	96″	F96T12/KF32/HO SFC	3200	Med. Bipin

(Continued)

Other Fluorescent Lamps			
Make and Name	**Color Temp (K)**	**Color Rendering Index**	**Minus-Green Correction Required**
Movie-Tone	3200	–	–
Movie-Tone	5500	–	–
GE Chroma 50	5000	90	$\frac{1}{2}$
GE IF 27	3000	–	–
GTE Sylvania Design 50	5000	91	$\frac{1}{2}$
Warm White (WW)	3000	52	Full
Deluxe Warm White (WWX)	3000	77	Full
Cool White (CW)	4500	62	Full

Colored Fluorescent Lamps	
Lamp	**Description**
Super Blue	420 nm blue spike for blue screen opticals
Green	560 nm green spike for green screen opticals
Black Light	UV A stimulates luminescent materials
Red	Party colors
Pink	Party colors
Yellow	Party colors

Table B.3 Tungsten Lamp Specifications and Substitutions

Bi-Pin Single-Ended Tungsten Halogen Lamps							
Watts	**ANSI Code**	**Color Temp (K)**	**LCL**	**Finish**	**Volts**	**LampLife (h)**	**Amps**
100 and 200 W Fresnels: Peppers, Midget, Tiny Mole, Mini Mole, etc.							
Base: Double-contact bayonet candelabra RX7. Lamps: B-12, G-16$\frac{1}{2}$, T-4 and T-8							
Burn within 30 of vertical, base down							
250	ESS	2950	$1\frac{3}{8}''$	C	120	2000	2.1
200	**FEV**	**3200**	$1\frac{3}{8}''$	**C**	**120**	**50**	**1.7**
200	BDJ	3200	$1\frac{3}{8}''$	C	120	20	1.7
200	CCM	3075	$1\frac{3}{8}''$	C	115-125	25	1.7
150	CGP	3075	$1\frac{3}{8}''$	C	115-120	25	1.3
150	ETF	3000	$1\frac{3}{8}''$	F	120	2000	1.3
150	ESP	2900	$1\frac{3}{8}''$	C	120	1000	1.3
150	ETC	3000	$1\frac{3}{8}''$	C	120	2000	1.3

Continued

Table B.3 Tungsten Lamp Specifications and Substitutions—cont'd.

Bi-Pin Single-Ended Tungsten Halogen Lamps							
Watts	**ANSI Code**	**Color Temp (K)**	**LCL**	**Finish**	**Volts**	**LampLife (h)**	**Amps**
100	**ESR**	**2850**	$1\frac{3}{8}''$	**C**	**120**	**750**	**0.5**
100	100Q/CL/DC	3000	$1\frac{3}{8}''$	C	120	1000	0.8
100	CEB	2975	$1\frac{3}{8}''$	C	115-125	50	0.8
75	CBX	2925	$1\frac{3}{8}''$	C	115-125	50	0.6
50	CAX	2875	$1\frac{3}{8}''$	C	115-125	50	0.4
100 W and 150 W Dedo							
Base: Small 2-pin: 2 PM = G 5.3 Lamp: T-3$\frac{1}{2}$, T-4. Burn base down to horizontal							
150	**FCS**	**3400**	**1.181″**	**C**	**24**	**100**	**6.25**
100	**FCR**	**3300**	**1.181″**	**C**	**12**	**50**	**8.3**
50	BRL	3300	1.181″	C	12	50	4.2
300 W, 650 W Fresnels: Tweenie II, Betweenie, 300 W Pepper, etc.							
Base: Small 2-pin prefocus: 2 PP = GY 9.5. GZ 9.5. Lamp: T-6. Burn with coil horizontal							
650	**FRK**	**3200**	$1\frac{13}{16}^{2}$	**C**	**120**	**200**	**5.4**
500	FRB	3200	$1\frac{13}{16}''$	C	120	200	4.2
300	**FKW**	**3200**	$1\frac{13}{16}^{2}$	**C**	**120**	**200**	**2.5**
Small 1k Fresnels (special high-seal-temp lamp made for specially designed high-temp heads—Sachtler, Desisti)							
Base: Small 2-pin prefocus GY9.5. Lamp: Philips							
1000	Blue Pinch	3200	$1\frac{13}{16}''$	C	120	250	8.3
Old Style Tweenie, 420 Pepper, Teenie Weenie Open Face							
Base: 2-pin prefocus: 2 PP = GY 9.5. GZ 9.5. T-6 or T-7 lamp. Burn with coil horizontal							
650	**EKD-Q650/3CL2PP**	**3400**	$1\frac{7}{16}''$	**C**	**120**	**25**	**5.4**
600	**DYS/DYV/BHC**	**3200**	$1\frac{7}{16}''$	**C**	**120**	**75**	**50**
420	**EKB-Q420/4CL/2PP**	**3200**	$1\frac{7}{16}''$	**C**	**120**	**75**	**2.5**
250	**DYG-Q250/4CL/2PP**	**3400**	$1\frac{7}{16}''$	**C**	**30**	**15**	**5.3**
100	EYL	3300	$1\frac{7}{16}''$	C	12	50	63
1k Fresnels							

(Continued)

Base: Medium bipost, G22. Lamp: T-6, T-7, T-20, or T-24. Burn within 45 of vertical base-down							
1000	**EGT-Q1000T7/4CL**	**3200**	$2\frac{1}{2}''$	**C**	**120**	**250**	**8.3**
1000	EGT	3200	$2\frac{1}{2}''$	C	120	250	8.3
1000	EBB-1M24/13	3350	$2\frac{1}{2}''$	C	120	12	8.3
750	EGR-Q750T7/4CL	3200	$2\frac{1}{2}''$	C	120	200	6.3
750	EGR	3200	$2\frac{1}{2}''$	C	120	200	6.3
750	DVH-750T24/16	3200	$2\frac{1}{2}''$	C	120	50	6.3
500	EGN	3200	$2\frac{1}{2}''$	C	120	100	4.2
500	DVG-500T20/63	3200	$2\frac{1}{2}''$	C	120	50	4.2
Small 2k Fresnels (special high-seal-temp lamp made for specially designed high-temp heads—Sachtler, Desisti)							
Base: Medium bipost, G22. Lamp: T-8 Philips							
2000	Blue Pinch	3200	$2\frac{1}{2}''$	C	120	500	16.7
2k Fresnels							
Base: Mogul bipost, G38. Lamp: T-7, T-8, T-9 1/2, and T-48. Burn within 45° of vertical base down.							
2000	**CYX-Q2000T10/4**	**3200**	**5″**	**C**	**120**	**250**	**16.7**
1500	CXZ-Q1500T10/4CL	3200	5″	C	120	300	12.5
1000	CYV-Q1000T7/4CL/BP	3200	5″	C	120	200	5.3
5k Fresnel							
Base: Mogul bipost, G38. Lamp: T-17 and T-20. Burn base-down to horizontal							
5000	**DPY-Q5000T20/4CL**	**3200**	$6\frac{1}{2}''$	**C**	**120**	**500**	**41.6**
5000	DPY	3200	$6\frac{1}{2}''$	C	120	500	41.6
10k and 12k Tungsten Fresnel							
Base: Mogul bipost, G38. Lamp: T-24. Burn within 45° of vertical base-down							
10,000	**DTY**	**3200**	**10″**	**C**	**120**	**300**	**83.3**
12,000	**Koto 12k**	**3200**	**10″**	**C**	**120**	**–**	**100**
20k Fresnel							
Base: Mogul bipost, G38. Lamp: T32. Burn within 45° of vertical, base-down							
20,000	KP200 208V	3200	13.937″	C	208	300	83.3
20,000	KP200 220V	3200	13.937″	C	220	300	83.3
20,000	**KP200 240V**	**3200**	**13.937″**	**C**	**240**	**300**	**83.3**

Continued

Table B.3 Tungsten Lamp Specifications and Substitutions—cont'd.

Watts	ANSI Code	Color Temp (K)	LCL	Finish	Volts	LampLife (h)	Amps
Bi-Pin Single-Ended Tungsten Halogen Lamps							
1k Molipso							
Base: Medium prefocus, P28. Lamp: T-5 or T-6. Burn any position							
1000	**EGJ-Q1000/ 4CL/P**	**3200**	$3\frac{1}{2}''$	**C**	**120**	**500**	**8.3**
1000	EGM-Q1000/ CL/P	3000	$3\frac{1}{2}''$	C	120	2000	8.3
1000	EGJ	3200	$3\frac{1}{2}''$	C	120	400	8.3
750	EGF-Q750/ 4CL/P	3200	$3\frac{1}{2}''$	C	120	500	8.3
750	EGG-Q750/ CL/P	3000	$3\frac{1}{2}''$	C	120	2000	6.3
750	EGF	3200	$3\frac{1}{2}''$	C	120	250	6.3
750	EGG	3000	$3\frac{1}{2}''$	C	120	2000	6.3
2k Molipso							
Base: Mogul bipost, G38. T-8 lamp. Burn any position							
2000	**BWA-Q2000/ 4CL/**	**3200**	**5″**	**C**	**120**	**750**	**16.7**
2000	BWA	3200	5″	C	120	500	16.7
1k Molette, Ellipsoidal Spotlights							
Base: Medium 2-pin. Lamp: G9.5. T-4 or T-6. Burn any position							
1000	**FFL-Q1000/ 4CL**	**3200**	$2\frac{3}{8}''$	**C**	**120**	**500**	**8.3**
1000	**FCV-Q1000/4**	**3200**	$2\frac{3}{8}''$	**F**	**120**	**500**	**8.3**
1000	FEL	3200	$2\frac{3}{8}''$	C	120	300	8.3
1000	FCV	3200	$2\frac{3}{8}''$	F	120	300	8.3
750	EHF-Q750/ 4CL	3200	$2\frac{3}{8}''$	C	122	300	6.3
750	EHF	3200	$2\frac{3}{8}''$	C	120	300	6.3
750	EHG	3000	$2\frac{3}{8}''$	C	120	2000	6.3
500	FHC/EHB	3200	$2\frac{3}{8}''$	C	120	200	4.2
500	EHC/EHB- Q500/5CL	3150	$2\frac{3}{8}''$	C	120	300	4.2
500	**EHD- Q500CL/TP**	**3000**	$2\frac{3}{8}''$	**C**	**120**	**2000**	**4.2**
500	EHD	3000	$2\frac{3}{8}''$	C	120	2000	4.2
2k Molette							
Base: Mogul screw. T-8 lamp. Burn any position							
2000	BWF-Q2000/ 4CL	3200	$5\frac{1}{4}''$	C	120	750	16.7

(Continued)

2000	BWF	3200	$5\frac{1}{4}''$	C	120	400	16.7
2000	**BWG**	**3200**	$5\frac{1}{4}''$	**F**	**120**	**400**	**16.7**
Double-Ended Tungsten Lamps							
Watts	**ANSI Code**	**Color Temp (K)**	**MOL**	**Finish**	**Volts**	**Lamp Life (h)**	**Amps**
400 and 650 W Soft Lights and Open-Face Lights							
Base: Recessed single-contact R7S. $3^1/_8''$ double-ended T-4 lamp. Burn any position							
650	**FAD**	**3200**	$3\frac{1}{8}''$	**C**	**120**	**100**	**5.4**
650	FBX	3200	$3\frac{1}{8}''$	F	120	100	5.4
650	DWY	3400	$3\frac{1}{8}''$	C	120	25	5.4
420	FFM	3200	$3\frac{1}{8}''$	C	120	75	3.5
400	**FDA (400T4Q/ 4CL)**	**3200**	$\mathbf{3\frac{1}{8}^{2}}$	**C**	**120**	**250**	**3.3**
400	EHR (400T4Q/CL)	2900	$3\frac{1}{8}''$	C	120	2000	3.3
300	EHP (300T4Q/CL)	2900	$3\frac{1}{8}''$	C	120	2000	2.5
1k Open-Face, Mickey, 1k Arrilite							
Base: Recessed single-contact R7s. Lamp: $3\frac{3}{4}''$ double-ended T-3. Burn any position							
1000	**DXW**	**3200**	$3\frac{3}{4}''$	**C**	**120**	**150**	**8.3**
1000	FBY	3200	$3\frac{3}{4}''$	F	120	150	8.3
1000	BRH	3350	$3\frac{3}{4}''$	C	120	75	8.3
1000	DXN	3400	$3\frac{3}{4}''$	C	120	75	5.0
600	FCB	3250	$3\frac{3}{4}''$	C	120	75	5.0
500	FGD	3200	$3\frac{3}{4}''$	C	120	100	4.2
Watts	**ANSI Code**	**Color Temp (K)**	**LCL**	**Finish**	**Volts**	**Lamp Life (h)**	**Amps**
1k Nook, 1k, 2k, 4k, and 8k Soft Lights							
Base: Recessed single-contact R7Ss. Lamp: $4\frac{11}{16}''$ double-ended T-3. Burn horizontal							
1000	**FCM-Q1000T3/ 4CL**	**3200**	$4\frac{11}{16}''$	**C**	**120**	**500**	**8.3**
1000	FCM-Q1000T3/4	3200	$4\frac{11}{16}''$	F	120	500	8.3
1000	FCM	3200	$4\frac{11}{16}''$	C	120	300	8.3
1000	**FHM**	**3200**	$4\frac{11}{16}''$	**F**	**120**	**300**	**8.3**
750	EJG-Q750T3/ 4CL	3200	$4\frac{11}{16}''$	C	120	400	8.3
750	EMD-Q750T3/4	3200	$4\frac{11}{16}''$	F	120	400	6.3
750	**EJG**	**3200**	$4\frac{11}{16}^{2}$	**C**	**120**	**400**	**6.3**

Continued

Table B.3 Tungsten Lamp Specifications and Substitutions—cont'd.

Watts	ANSI Code	Color Temp (K)	LCL	Finish	Volts	LampLife (h)	Amps
Bi-Pin Single-Ended Tungsten Halogen Lamps							
500	FDF-Q500T3/4CL	3200	$4\frac{11}{16}''$	C	120	400	4.2
500	FDN-Q500T3/4	3200	$4\frac{11}{16}''$	F	120	400	4.2
500	EDF	3200	$4\frac{11}{16}''$	C	120	400	4.2
500	EDN	3200	$4\frac{11}{16}''$	F	120	400	4.2
500	Q500T3/CL	3000	$4\frac{11}{16}''$	C	120	2000	4.2
500	Q500T3	3000	$4\frac{11}{16}''$	F	120	2000	4.2
500	FCL	3000	$4\frac{11}{16}''$	C	120	2600	4.2
500	FCZ	3000	$4\frac{11}{16}''$	F	120	2600	4.2
300	EHM-Q300T2 1/2/CL	2980	$4\frac{11}{16}''$	C	120	2000	2.5
300	EHZ-Q300T2 1/2	2950	$4\frac{11}{16}''$	F	120	2000	2.5
2k Nook							
Base: Recessed single-contact R7s. Lamp: $5\frac{5}{8}''$ double-ended T-6 or T-8. Burn any position							
2000	**FEY-Q2000T8/4CL**	**3200**	$5\frac{5}{8}''$	**C**	**120**	**500**	**16.7**
2000	FEY (2MT8Q/4CL)	3200	$5\frac{5}{8}''$	C	120	400	16.7
1000	FER/EHS-Q1000T4/6CL	3200	$5\frac{5}{8}''$	C	120	500	8.3
1000	FER (1000T6Q/4CL)	3200	$5\frac{5}{8}''$	C	120	500	8.3
1000	DWT-Q1000T6/CL	3000	$5\frac{5}{8}''$	C	120	2550	8.3
1000	DWT (1000T6Q/CL)	3000	$5\frac{5}{8}''$	C	120	2000	8.3
Cyc Strips							
Base: Recessed single-contact R7s. Lamp: $6\frac{9}{16}''$ double-ended T-3 or T-4. Burn horizontal $\pm 4°$							
1500	**FDB-Q1500T4/4CL**	**3200**	$6\frac{9}{16}''$	**C**	**120**	**400**	**12.5**
1500	FGT-Q1500T4/4	3200	$6\frac{9}{16}''$	F	120	400	12.5

(Continued)

1000	**FFT-Q1000T3/1CL**	**3200**	**$6\frac{9}{16}''$**	**C**	**120**	**400**	**8.3**
1000	FGV-Q1000T3/1	3200	$6\frac{9}{16}''$	C	120	400	8.3

LCL, light center length, the distance from the center of the lamp's filament to the bottom of its base. If the wrong LCL is used, the filament will not be centered on the reflector and fixture performance will be greatly reduced.
MOL, maximum overall length, the distance from the top of the lamp to the tip of the pins on the base or from end to end for double-ended lamps. For double-ended lamps, MOL is necessary to match lamp to fixture size.
Interchangeability, lamps within each grouping in this table are interchangeable—they have the same base (type and dimensions) and the same LCL (or MOL, in the case of double-ended lamps).
The most commonly used lamps for motion picture work are highlighted in bold print.
C, clear finish; F, frosted finish.

Table B.4 PAR 64 Lamps, 120 V, EMEP Base (Extended Mogul End Prong)

		1000 W			
Beam	**500 W 2800 K (2000 h)**	**3000 K (4000 h)**	**3200 K (800 h)**	**5200 K (200 h)**	**1200 W 3200 K**
Very narrow spot	–	–	FFN (VNSP)	–	GFC
			Q1000PAR64/1		(VNSP)
Narrow spot	500PAR64NSP	1000PAR64QNSP	FFP (NSP)	FGM (NSP)	GFB (NSP)
			Q1000PAR64/2	Q1000PAR64/3D	
Medium flood	500PAR64MFL	1000PAR64QMFL	FFR (MFL)	FGN (MFL)	GFA (MFL)
			Q1000PAR64/5	Q1000PAR64/7D	
Wide flood	500PAR64WFL	1000PAR64QWFL	FFS (WFL)	–	GFE (WFL)
			Q1000PAR64/6		
Extra-wide flood	–	–	GFF (XWFL)	–	GFD (XWFL)

Table B.5 PAR 64 Lamp Performance Data for PAR 64 and Aircraft Landing Lights

ANSI Code	Volts	Watts	Base	Color Temp	Avg. Life (h)	Beam	Beam Angle (°)	Candle Power
FFN	120	1000	EMEP	3200	800	VNSP	12 × 6	400,000
FFP	120	1000	EMEP	3200	800	NSP	14 × 7	330,000
FFR	120	1000	EMEP	3200	800	MFL	28 × 12	125,000
FFS	120	1000	EMEP	3200	800	WFL	48 × 24	40,000
GFF	120	1000	EMEP	3200	800	XWFL	–	–
GFC	120	1200	EMEP	3200	400	VNSP	10 × 8	540,000
GFB	120	1200	EMEP	3200	400	NSP	10 × 8	450,000
GFA	120	1200	EMEP	3200	400	MFL	24 × 13	160,000
GFE	120	1200	EMEP	3200	400	WFL	58 × 25	45,000
GFD	120	1200	EMEP	3200	400	XWFL	–	–
ACL (Aircraft Landing Light) Lamps in PAR 64 Size								
4559	28	600	Screw Terminal	–	25	VNSP	12 × 11	600,000
Q4559	28	600	Screw Terminal	_–	100	VNSP	12 × 8	600,000
Q4559X	28	600	Screw Terminal	–	100	VNSP	$11 \times 7\frac{1}{2}$	600,000

Table B.6 PAR 36 Lamps, 650 W, 120 V, Ferrule Base

Beam	5000 K (35 h)	3400 K (30 h)	3200 K (100 h)
Spot	–	FBJ Q650PAR36/3–	–
Medium	FAY Q650PAR36/3D	DXK Q650PAR36/2	FCX Q650PAR36/7
Wide	–	–	FCW Q650PAR36/6

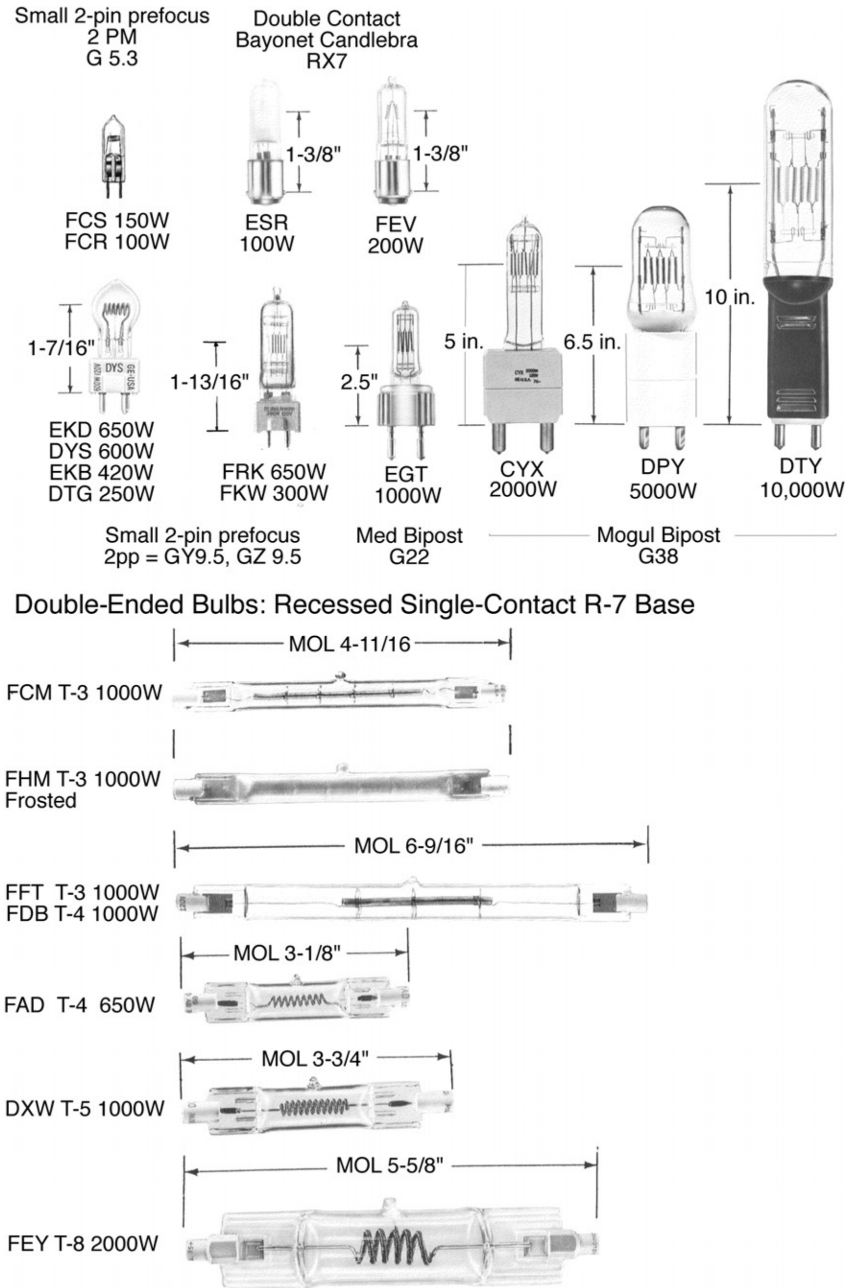

FIGURE B.1

Tungsten halogen lamps.

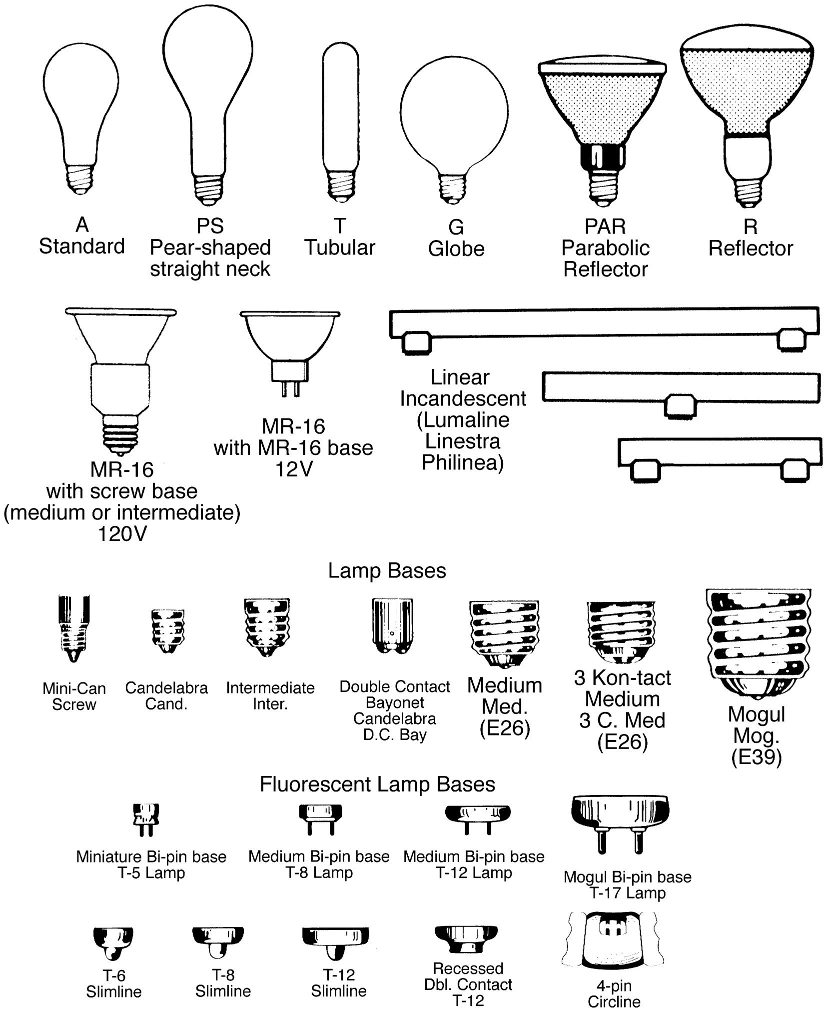

FIGURE B.2

Various types of practical lamps and lamp bases.

APPENDIX

C

Flicker-free frame rates

Table C.1 HMI Flicker-Free Frame Rates at Any Shutter Angle: **60 Hz Power**

Frames/s	Optimal Shutter Angle
120.000	180
60.000	180
40.000	120
30.000	180
24.000	144
20.000	180
17.143	
15.000	
13.333	
12.000	180
10.909	
10.000	
9.231	
8.000	198
7.058	
6.000	
5.000	
4.000	
3.000	
2.000	
1.000	

Table C.2 Additional Flicker-Free Frame Rates at Specific Shutter Angles: **60 Hz Power**

Frames/s	Shutter Angle
57.6	172.8
50	144
48	144
45	135
36	108
35	105
32	92 or 96
28	168
26	156
25	150
22	198 or 132
18	162
16	192 or 144

Table C.3 Flicker-Free Frame Rates at Any Shutter Angle: **50 Hz Power**

Frames/s	Optimal Shutter Angle
100.000	180
50.000	180
33.333	
25.000	180
20.000	144
16.666	
14.285	
12.500	
11.111	
10.000	
9.090	
8.333	
7.692	
7.142	
6.666	
5.000	
4.000	
3.125	
2.500	
2.000	
1.000	

Table C.4 Additional Flicker-Free Frame Rates at Specific Shutter Angles: **50 Hz Power**

Frames/s	Shutter Angle
48	172.8
40	144
36	129.6
32	115.2
30	108
28	108.8
26	187.2 or 93.6
24	172.8
22	158.4
18	194.4 or 129.6
16	172.8 or 115.2
12	172.8 or 129.6
8	172.8 or 144

Electrical tables

D

Table D.1 Ampacity of Cables: Type W and Entertainment Industry Stage Cable (EISC) Types SC, SCE, and SCT[a] (NEC Table 400-5(B))

	No. of Current-Carrying Wires in Cable		
Size of Cable	**1**	**2[b]**	**3[c]**
Cable Rated at 90 and 105 °C			
4/0	405	361	316
3/0	350	313	274
2/0	300	271	237
1/0	260	234	205
2 AWG	190	174	152
4 AWG	140	130	114
6 AWG	105	99	87
8 AWG	80	74	65
Cable Rated at 75 °C			
4/0	360	317	277
3/0	310	275	241
2/0	265	238	208
1/0	230	207	181
2 AWG	170	152	133
4 AWG	125	115	101
6 AWG	95	88	77
8 AWG	70	65	57
Cable Rated at 60 °C			
4/0	300	265	232
3/0	260	230	201
2/0	225	199	174
1/0	195	173	151
2 AWG	140	128	112
4 AWG	105	96	84

Continued

Table D.1 Ampacity of Cables: Type W and Entertainment Industry Stage Cable (EISC) Types SC, SCE, and SCT[a] (NEC Table 400-5(B))—cont'd

	No. of Current-Carrying Wires in Cable		
Size of Cable	**1**	**2[b]**	**3[c]**
6 AWG	80	72	63
8 AWG	60	55	48

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[a]*These amperage capacities are based on an ambient temperature of 30 °C (86 °F). They are allowable only where the individual conductors are not installed in raceways and are not in physical contact with one another, except in lengths not to exceed 24 in. where passing through the wall of an enclosure.*

[b]*See footnote* b *in Table D.2.*

[c]*See footnote* c *in Table D.2.*

Table D.2 Amperage Capacities for Flexible Cords, Stingers, and Zip Cord[a] (NEC Table 400-5(A))

	No. of Current-Carrying Wires		
AWG Size	**2[b]**	**3[c]**	**Asbestos[d]**
18	10	7	6
16	13	10	8
14	18	15	17
12	25	20	23
10	30	25	28
8	40	35	–
6	55	45	–
4	70	60	–
2	95	80	–

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[a]*These amperage capacities apply to the following types of cord: thermoset types C, E, EO, PD, S SJ, SJO, SJOO, SO, SOO, SP-1, SP-2, SP-3, SRD, SV, SVO, and SVOO and thermoplastic types ET, ETT, ETLB, SE, SEO, SJE, SJEO, SJT, SJTO, SJTOO, SPE-1, SPE-2, SPE-3, SPT-1, SPT-2, SPT3, ST, STO, STOO, SRDE, SRDT, SVE, SVEO, SVT, SVTO, and SVTOO.*

[b]*The amperage capacities in this column apply to multiconductor cable in which two of the wires are current-carrying (such as a hot wire and a neutral wire, or two hot wires of a 240 V single-phase circuit). The neutral wire of a balanced 240/120 V single-phase circuit is not considered a current-carrying wire for the purpose of this table, with one exception: if the major portion of the load consists of electronic ballasts, electronic dimmers, or similar equipment, there are harmonic currents present in the neutral conductor and it shall be considered to be a current-carrying conductor. The green grounding wire is never considered to be a current-carrying wire.*

[c]*The amperage capacities in this column apply to multiconductor cable in which three of the wires are current-carrying wires (such as a three-wire three-phase-circuit, a balanced four-wire three-phase circuit, or a single-phase three-wire circuit derived from the neutral and two-phased legs of a wye-connected three-phase system). The neutral wire of a balanced four-wire three-phase circuit is considered a current-carrying wire only when there are harmonic currents present. A cord or cable with four or more current-carrying wires must be derated in accordance with NEC Section 400-5. Cords and cables in which four to six of the conductors are carrying current must be derated to 80% of the ampacities given in this table.*

[d]*This column gives the amperage capacities of asbestos cords (types AFC, AFPD, and AFPO), which are often used inside fixtures.*

Table D.3 Minimum Size of Grounding Wires (NEC Table 250-95)

Rating of Overcurrent	Gauge of Grounding Conductor Aluminum and Copper-Clad	
Protection of Circuit (A)	**Copper Wire No.**	**Aluminum Wire No.**
15	14 AWG	12 AWG
20	12 AWG	10 AWG
30	10 AWG	8 AWG
40	10 AWG	8 AWG
60	10 AWG	8 AWG
100	8 AWG	6 AWG
200	6 AWG	4 AWG
300	4 AWG	2 AWG
400	3 AWG	1 AWG
500	2 AWG	1/0
600	1 AWG	2/0
800	1/0	3/0
1000	2/0	4/0
1200	3/0	250 kcmil
1600	4/0	350 kcmil

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Table D.4 Resistance, Weight, and Cross-Sectional Area of Copper Wire

Size	Approx OD inches	Cross-Sectional Area (cmil)	Lb. per M/100 ft.	Ohms per M/100 ft.	ft./Ohm
4/0	0.528	21,1600	65.3	0.00509	19,646
2/0	0.418	133,100	41.1	0.00811	12,330
2 AWG	0.292	66,360	20.5	0.0162	6173
4 AWG	0.232	41,740	12.9	0.0259	3861
6 AWG	0.184	26,240	8.0	0.0410	2439
8 AWG	0.1285	16,510	5.1	0.0640	1529
10 AWG	0.1019	10,380	3.1	0.1018	981.9
12 AWG	0.0808	6530	20.0	0.1619	617.0
14 AWG	0.0641	4110	1.2	0.2575	389.0
16 AWG	0.0508	2580	.8	0.4094	244.0
18 AWG	0.0403	1620	.5	0.6510	154.0

Note*: Weights listed are of the copper itself, not the total weight of an insulated cable. Resistance at 25 °C.*

APPENDIX

IP and NEMA equipment ratings

E

INTERNATIONAL PROTECTION RATINGS

Lights and equipment that may be exposed to the elements, such as dew, rain, splashing water, mist, and so on, require an enclosure that prevents water from getting inside. This is known as ingress protection. The Comission Electrotechnique International (IEC), the body responsible for international electrical standards, created an International Protection (IP) rating standard in 1989. The IP rating signifies the degree to which a light enclosure can protect against ingress of water and particulates. The IP rating can usually be found next to the UL listing stamp on the fixture. It begins with the letters "IP," followed by two numbers. The first is a number from 0 to 6, which refers to the ingress size in millimeters (as shown below). This is the rating of protection against foreign objects such as fingers, leaves, feathers, and dust. The second is a number from 0 to 8, which refers to the ingress of water:

First number—Objects

0	not protected
1	≥50 mm diameter
2	≥12.5 mm diameter
3	≥2.5 mm diameter
4	≥1.0 mm diameter
5	dust protection
6	dust tight

Second number—Water

0	not protected
1	protection against vertically dripping water
2	protection against dripping water at up to 60° angle from the vertical
3	protection against water spray at up to 60° angle from the vertical
4	protection against splashing water from all directions
5	protection against low-pressure jetting water from all directions
6	protection against a powerful jet of water from all directions
7	protection against temporary immersion in water less than 1 m deep
8	protection against continuous immersion in water at a specified depth

Optional letters may follow the IP numbers:

A	Protection against contact with back of hand
B	Protection against contact with finger
C	Protection against contact with a tool such as a screwdriver
D	Protection against contact with wire
H	Protection against high-voltage apparatus
M	Enclosure was in motion during water testing
S	Enclosure was stationary during water testing
W	Protection against weather

NEMA RATINGS

Similarly the *National Electrical Manufacturers Association (NEMA Enclosures Section)* specifies four Types of equipment, which—similar to the IP system—may be followed by modifying letters: Type 1, Type 2, Type 3, Type 3R, Type 3S, Type 3X, Type 3SX, Type 4, and Type 4X.

In nonhazardous locations, the specific enclosure types, their applications, and the environmental conditions they are designed to protect against, *when completely and properly installed*, are as follows:

Type 1	Enclosures constructed for *indoor use* to provide a degree of protection to personnel against *access to hazardous parts*. Provides a degree of protection of the equipment inside the enclosure against *ingress of solid foreign objects (falling dirt)*
Type 2	All the conditions of Type 1, plus provides a degree of protection with respect to harmful effects due to the *ingress of water (dripping and light splashing)*
Type 3	All the conditions of Type 2, plus enclosures constructed for indoor or *outdoor use*, and provides a degree of protection from *ingress of windblown dust*, and is undamaged by the external *formation of ice* on the enclosure
Type 4	All the conditions of Type 3, plus a degree of protection with respect to harmful effects on the equipment due to the ingress of water (*rain, sleet, snow, splashing water, and hose-directed water*)

Modifying letters

R	Does *not* provide protection from *ingress of windblown dust*
S	*External mechanism(s) remain operable when ice-laden*
X	Additional level of protection against *corrosion*

Equipment suppliers and manufacturers

F

AC Power Distribution, Burbank, CA. Distribution boxes. http://www.acpowerdistribution.com
Airstar. Lenix helium balloon lights. http://www.airstar-light.com
Altman Stage Lighting Company, Yonkers, NY. Tungsten and HMI fixtures, ellipsoidal and theatrical fixtures. LED fixtures. http://www.altmanltg.com
American Grip Inc., Sun Valley, CA. Studio and grip equipment. http://www.americangrip.com
Amphenol Socapex. Interconnect systems. http://www.amphenol-socapex.com
Appolo Design Technology, Inc. Gels and lighting accessories. http://www.apollodesign.net
ARRI, Burbank, CA. Tungsten, HMI, Fluorescent, LED lights, remote yoke for large HMIs, stands and grip equipment. http://www.arri.com
Automated Entertainment, Burbank, CA. Range of dichroic filters, blacklights, fully stocked theatrical rental house. http://www.automatedhd.com
Avenger Grip. See Bogen Imaging.
Backstage Studio Equipment, North Hollywood, CA. Studio equipment. http://www.backstageweb.com
Bardwell McAlister Inc. (B&M), Sun Valley, CA. Lights, HLP spacelights, Mac Tech HPL Maxi and HPL Space Light, Fresnel and soft lights. http://bmlighting.com/site/
Barger Light, Venice, CA. Soft light bags and heads. http://www.barger-baglite.com
Baxter Controls, Inc., Driftwood, TX. Pocket Console (DMX512). http://dmx2go.com
Bender, Coatesville, PA. GFCI distribution equipment. http://www.bender.org
Benjamin Electric Co., Los Angeles, CA. Distribution boxes, deuce boards, studio distribution equipment. http://www.benjaminelectric.com
Blender Lights. LED lens lights. http://blenderlights.com/tech.html
Bogen Imaging. Lighting stands, clamps, and grip hardware. Now called Manfrotto Distribution. http://www.bogenimaging.us/Jahia/home_page
Carol Cable Co., Inc., Pawtucket, RI. Cable. http://www.generalcable.com/GeneralCable/
Chimera Photographic Lighting, Boulder, CO. Soft boxes. http://www.chimeralighting.com
Cinemills Corp., Burbank, CA. Tungsten and HMI lights, gel. http://www.cinemills.com
City Theatrical. Unique aftermarket lighting accessories, especially for theatrical and touring fixtures, SHoW DMX wireless DMX systems, mounting clamps, LED power supplies, etc. http://www.citytheatrical.com
Clairmont Camera, North Hollywood, CA. Synchronous strobe system, camera rental. http://www.clairmont.com
Clay Paky. Moving lights. www.claypaky.it/en/home/

Dadco LLC, Sun Valley, CA. Portable Power Distribution Systems, tungsten and HMI lights. http://www.dadcopowerandlights.com

Desisti. Tungsten and HMI lights. http://www.desistilighting.com

Doug Fleenor Enterprises, Arroyo Grande, CA. DMX testers, opto-splitters, isolators, converters. http://www.dfd.com

Elation Professional. Theatrical, venue lighting, including moving lights and LED lights. http://www.elationlighting.com

Electronic Theatre Controls (ETC), Middleton, WI. Control consoles, dimmer systems, ellipsoidal and PAR fixtures, LED systems. http://www.etcconnect.com

Element Labs. Versa tubes and other LED pixel-mapping applications, Kelvin Tile. LED set pieces. http://www.elementlabs.com

Entertainment Technology (Philips). Reverse phase control (GFCI) dimmer systems. http://www.etdimming.com

ESP Vision. Lighting previsualization software. http://www.espvision.com

ExCel Wire and Cable Co. Cable.

Filmtools, Burbank, CA. Retailer of all manner of production supplies and lighting gear. http://www.filmtools.com

Firefly. Lighted cable protectors. http://www.fireflycableprotector.com/Distributors.html

Fisher Lights, North Hollywood, CA. Large softboxes for car photography, soft light crane light. Rep for other lights. http://www.fisherlight.com

Fluke Electronics, Everett, WA. Electrical meters and test equipment. http://us.fluke.com

Gekko Technology, LTD, Kenilworth, UK. LED lights for motion picture production. http://www.gekkotechnology.com

General Electric, Cleveland, OH. Tungsten and HMI bulbs. http://gelighting.com

Genie Industries USA, Redmond, WA. Man lift. http://www.genielift.com

Giddings Pace, Inc., Sun Valley, CA. Underwater HMI lights. http://www.pacetech.com

Goddard Design Co. RDM and DMX512 testing equipment. http://www.goddarddesign.com

GAM (Great American Market). Stickup lights, flicker boxes, GAM gels, color changers. http://www.gamonline.com/

Group 5 Bates Connectors (Marinco Electrical Group). Bates connectors. High-power flashlights. http://www.marinco.com

High End Systems, Austin, TX. Control consoles, automated lights. http://www.highend.com

Honda Generators. http://www.hondapowerequipment.com

HydroFlex, Inc., Los Angeles, CA. Underwater lights. Splash housings for lights and cameras. http://www.hydroflex.com

ILC Technology Inc., Sunnyvale, CA. HMI bulbs. http://www.photonics.com

Illumination Dynamics. Lighting equipment rental, generators. http://www.illuminationdynamics.com

Jem Studio Lighting Inc., Van Nuys, CA. China lantern kits. http://jemlighting.com

K 5600, North Hollywood, CA. HMI Joker fixtures and 200 W Bug light and 200 W inverter. http://www.k5600.com

Kino Flo, Inc., Burbank, CA. Fluorescent systems for motion picture production. http://www.kinoflo.com

Komet. LED fixture. http://kometled.com

Koto, Di-Lite Taito-ku, Tokyo, Japan. HMI bulbs.

Lanternlock. Paper lantern holders. http://www.lanternlock.com
LEDStorm. LED light fixtures. http://ledstorm.com/ledstorm/
LED-Z LLC. LED brute lights. http://www.led-z.com
Lee Filters USA, Burbank, CA. Lee filters and gels. http://www.leefilters.com
Leelium Balloons Ltd., London UB5 5QQ England. Helium balloons. http://www.leeliumballoons.com
LEX. Distribution equipment, dimmers. http://www.lexProducts.com
Liberty Pak. Lithium-ion battery packs. http://www.libertypak.com
Light Control Concepts. Control grids for LitePanels lights. http://www.lightcontrolconcepts.com
Lightning Strikes/Luminys, Hollywood, CA. Lightning effects lights. http://www.luminyscorp.com
Litegear. Dimming fluorescent fixtures/ballasts, LightRibbon LEDs, and power supplies. http://www.litegear.com
LitePanels. LED light fixtures. http://www.litepanels.com
Lowel-Light Manufacturing, Inc., Hauppauge, NY. Tungsten fixtures. http://www.lowel.com
LRX. Large automated remote HMI lights. http://www.dwightcrane.com
LTM Corp. of America, Sun Valley, CA. Tungsten and HMI fixtures. http://www.ltmlighting.com
Luma Panels. See T8 Technologies.
Luminy Lightning Strikes. SoftSun. http://www.luminyscorp.com/
Magic Gadgets/William A. McIntire Enterprises, Portland, OR. Dimmers, flicker effects boxes, dimmers various gadgets. http://www.magicgadgets.com
Manfrotto Distribution. See Bogen Imaging.
Martin Professional, Moving Lights, LED cycs, and set pieces. http://www.martin.com
Matthews Studio Equipment, Inc., Burbank, CA. Studio equipment. http://www.msegrip.com
Minolta (Konic Minolta). Light meters. http://kmbs.konicaminolta.com
Mole-Richardson Co., Hollywood, CA. Tungsten and HMI fixtures, studio equipment, distribution equipment, carbon arc lights. http://www.mole.com
Movie-Tone Lighting. Color corrected fluorescent lamps. http://www.movie-tone.com/
Musco Mobile Lighting, Ltd., Oskaloosa, IA. Mobile lighting trucks. http://www.musco.com
Nila Lights. New York. LED light system. http://www.nila.tv
Norms, North Hollywood, CA. Studio grip equipment. http://normsgrip.com/
Osram Corp. Tungsten and HMI lamps.
Peterson Systems International, Duarte, CA. Cable crossovers. http://www.petersonsystems.com
Philips Color Kinetics. LED light fixtures. http://www.colorkinetics.com
Philips Lighting Co., Somerset, NJ. Bulbs. http://www.lighting.philips.com
Philips Lumileds. LED emitters. http://www.philipslumileds.com
Phoebus Manufacturing, San Francisco, CA. Xenon follow spots and searchlights, electronic shutters, xenon projectors, and other specialty items. http://www.phoebus.com
Power Gems Corporation. Electronic HMI ballasts, DMX-controlled HMI ballasts. http://www.cleararc.com
Power To Light. Electronic HMI ballasts. http://www.powertolight.com
PRG. Moving lights, control consoles, event design. http://www.prg.com
Rosco Laboratories, Inc. Gels. http://www.rosco.com
Royal Electric, Inc., Philadelphia, PA. Cable. http://www.royalelectric.com
Sachtler. Tungsten, HMI, fluorescent fixtures, LED lens light fixtures. http://www.sachtler.com

Saunders Electric. Generators and transformers. http://www.saunderselectric.com
Sekonic. Light measurement meters. http://www.sekonic.com
Shock Block (Littelfuse). K-tec circuit/safety protection for wet locations, ground fault relays. http://www.littelfuse.com/ktec/
Shotmaker. Custom tow vehicles. http://www.shotmaker.com
Show DMX. Wireless DMX system. http://www.citytheatrical.com/ShowDMX1.htm
Snorkelift. Telescoping boom platforms. http://www.snorkellift.com/AerialWorkPlatforms.aspx
SpectraCine, Inc., Burbank, CA. Light meters. http://www.spectracine.com
Strand Lighting, Inc., Philips Strand Lighting. Tungsten and HMI fixtures, ellipsoidal and theatrical fixtures, dimmer packs. http://www.strandlighting.com/
Strong International, Inc., Omaha, NE. Xenon, HMI, and tungsten follow spots. Xenon lights. http://www.strong-cinema.com
Swisson. DMX testing device. http://www.swisson.com
Sylvania. Tungsten and HMI bulbs. http://www.sylvania.com
T8 Technologies. Lumapanels large fluorescent Sofbanks. http://www.lumapanel.com
Teatronics. Dimmers. http://www.teatronics.com
The Light Source. Clamps, claws, and couplers. http://www.thelightsource.com
Unilux, Inc., Saddle Brook, NJ. Strobe lighting system. http://www.unilux.com
Union Connector, Roosevelt, NY. Distribution boxes, electrical connectors. http://www.unionconnector.com/
Ushio America, Inc. Tungsten bulbs, HPL lamps. http://www.ushio.com
Vari*lite, Philips/Vari-Lite. Moving lights and moving light control consoles. http://www.vari-lite.com
VEAM (a division of Litton Systems, Inc.), Watertown, CT. Electrical connectors.
Vectorworks Spotlight. Professional CAD Lighting Plot drafting software. http://www.nemetschek.net/spotlight
W-DMX. Wireless DMX systems. http://www.wirelessdmx.com
Wildfire Inc., Los Angeles, CA. Ultraviolet light technology. Black light Fresnel and theatrical fixtures, paints, and accessories. http://www.wildfirefx.com
Wolfram, Scotts Valley, CA. HMI lamps. http://www.wolframlights.com/
Woody Light, Inc., Granada Hills, CA. Versatile Soft light bank. http://www.woodylight.com
Xenotech, Inc. Strong Xenon lights. http://www.strong-cinema.com
Yellow Jacket. Cable protectors. http://www.yjams.com

APPENDIX

Lighting equipment order checklist

G

HMI fresnels

To include barn doors, five-piece scrim set, gel frame, scrim box, magnetic ballast, two 50-ft. head cables, ballast feeder cable.

__________ 18k Fresnel
__________ 12k Fresnel
__________ 6k Fresnel
__________ 4k Fresnel
__________ 2500 Fresnel
__________ 1200 Fresnel
__________ 575 Fresnel
__________ 200 Fresnel
__________ Electronic ballasts
__________ 12k clear glass lens

HMI pars

To include barn doors, three-piece scrim set, gel frame, scrim box, four- or five-piece lens set, magnetic ballast, two 50-ft. head cables, ballast feeder.

__________ 12/18k PAR
__________ 6k PAR
__________ 4k PAR
__________ 2500 W PAR
__________ 1200 W PAR
__________ 575 W PAR
__________ 400 W Joker
__________ 200 W PAR
__________ Electronic ballasts

Sun guns

__________ Sun Gun
__________ 30-V Ni-cad belt-battery
__________ AC power supply

Tungsten fresnels

To include five-piece scrim set, gel frame, scrim box or bag, four-leaf barn doors, power feeder.

__________ 20k Fresnel w/ramp-up dimmer
__________ 10k Studio Fresnel
__________ 10k Big Eye Fresnel
__________ 10k Baby Tenner
__________ 5k Studio Fresnel
__________ 5k Baby Senior
__________ 2k 8″ Junior Fresnel
__________ 2k Baby Junior Fresnel
__________ 2k Studio Junior Fresnel
__________ 1k Studio Fresnel (407)
__________ 1k Baby Baby Fresnel
__________ 650 W Fresnel
__________ 420 Pepper
__________ 300 Pepper
__________ 200 Pepper
__________ 200 W Midget/Tiny/Mini
__________ 100 W Pepper

Dedos

__________ 150 W Dedo Kit
__________ 100 W Dedo Kit
__________ 250 W Dedo Cool Kit

Fresnel accessories

__________ Snoots
__________ Focal spots
__________ Shutters
__________ Chimera banks
__________ Chimera speed rings

Tungsten soft lights

To include egg crate, power feeder.

__________ 8k Soft light
__________ 4k Soft light
__________ 4k Zip soft
__________ 2k Super soft
__________ 2k Zip soft

__________ 1k Zip soft
__________ 750 Zip soft
__________ 400 Soft

Tungsten open-face

To include five-piece scrim set, gel frame, scrim box or bag, four-leaf barn doors.

__________ 2k Mighty Mole
__________ 2k Blonde
__________ 1k Mickey Mole
__________ 1k Red head
__________ 650 Open-face
__________ 2k Nook
__________ 1k Nook
__________ 650 W Nook
__________ 1k Molette
__________ 2k Molette
__________ Pinza (Med. screw base)

Kits

__________ R-40 kit
__________ Lowel tape-up kit
__________ Stick-up kit

Tungsten pars

__________ 1k Molepar (with three-piece scrim set, barn doors)
__________ 1k PAR cans (with gel frame, bail block)
__________ Six-light PAR (6 PAR 64s)
__________ Maxi-Brute (9 PAR 64s)
__________ Dino (24 PAR 64s)
__________ Ultra Dino (36 PAR 64s)
__________ VNSP PAR 64
__________ NSP PAR 64
__________ MFL PAR 64
__________ WFL PAR 64
__________ Nine-light FAY
__________ Six-light FAY
__________ Four-light FAY
__________ Two-light FAY

__________ One-light FAY
__________ PAR 36 Dichroic
__________ PAR 36 Tungsten MFL
__________ PAR 36 Tungsten WFL

Tungsten area lights

__________ Skypan (10k, 5k, or 2k)
__________ Chicken coop 6k
__________ Spacelight 6k
__________ 2k Scoop light
__________ 1k Scoop light

Ellipsoidal spotlights

__________ Source Four 50°
__________ Source Four 36°
__________ Source Four 26°
__________ Source Four 19°
__________ Source Four 10°
__________ Source Four 5°
__________ Edison pigtails
__________ Bail blocks

Other theatrical lights

__________ Cyc strip
__________ Follow spot
__________ Beam projector
__________ Scene machine

Fluorescents

__________ Wall-O-Lite (10 bank)
__________ 4-ft. Four bank
__________ 4-ft. Double bank
__________ 4-ft. Single
__________ 2-ft. Four bank
__________ 2-ft. Double bank
__________ 2-ft. Single

__________ 15-in. Four bank
__________ 15-in. Double bank
__________ 15-in. Single
__________ 8-ft. tubes with slimline ballast
__________ 6-ft. tubes with slimline ballast
__________ 12 V Single 15-in. kit
__________ 12 V Mini Flo 9-in. kit
__________ 12 V Micro Flo 6-in. kit
__________ 12 V Micro Flo 4-in. kit

Xenons

__________ 10k Xenon
__________ 7k Xenon
__________ 4k Xenon
__________ 2k Xenon
__________ 1k Xenon
__________ 750 W Xenon
__________ 500 W Xenon
__________ 150 W Xenon
__________ 75 W Xenon flashlight

Stands

__________ Cinevator, Crank-o-vator
__________ Super Crank
__________ Crank-o-vator
__________ Low crank stand
__________ Mombo combo four-riser stand
__________ Steel three-riser junior stand
__________ Steel two-riser junior stand
__________ Aluminum three-riser junior
__________ Aluminum two-riser junior
__________ Junior rolling stand three-riser
__________ Junior rolling stand two-riser
__________ Low boy junior stand
__________ Steel three-riser baby stand
__________ Steel two-riser baby stand
__________ Baby rolling stand three-riser
__________ Baby rolling stand two-riser
__________ Low baby stand

__________ Preemie stand
__________ Blade stand
__________ Low blade stand
__________ Runway base
__________ Turtle stand
__________ T-bone
__________ Wheel set (three-piece)

Carts

__________ Cable cart
__________ Doorway dolly
__________ Head cart
__________ Milk-crate cart
__________ Work box

Dimmers

__________ Control console
__________ CD80 (6 × 100 A)
__________ CD80 (6 × 60 A)
__________ CD80 (24 × 20 A)
__________ CD80 (24 × 15 A)
__________ 20k Stand-alone dimmer
__________ 12k Stand-alone dimmer
__________ 6k Stand-alone dimmer
__________ 5k Variac
__________ 2k Variac
__________ 1k Variac
__________ 5k Plate dimmer
__________ 3k Plate dimmer
__________ 2k Plate dimmer
__________ 1k Plate dimmer
__________ 1k Hand dimmer
__________ 650 W Hand dimmer

Distribution

__________ Three-bar spider box
__________ Four-bar spider box
__________ Five-bar spider box
__________ 600 A Bull switch three-phase
__________ 400 A Bull switch single-phase

__________ 200 A bull switch single-phase
__________ 900 A Distro box
__________ 600 A Distro box
__________ 400 A Banded box
__________ Lug to female adapters
__________ Lug to male adapters
__________ Three-fers (pin)
__________ Ground squid (pin)
__________ Female suicide pin adapter
__________ Male suicide pin adapter
__________ Cam-Lok T-splitter
__________ Lug to Cam-Lok jumper
__________ Two-wire pin to 100 A 240-V Bates adapter
__________ Two-wire pin to 100 A Bates adapter
__________ Three-wire pin to two 100 A Bates adapter
__________ 100 A to two 100 A Bates adapter
__________ 100 A to two 60 A Bates adapter
__________ 60 A to two 60 A Bates adapter
__________ 100 A Lunch box (five duplex Edison outlets with circuit beakers)
__________ 100 A Gang box (five 20 A fused Edison)
__________ 60 A Gang box
__________ Inline hertz meter
__________ Flicker box
__________ Cable crossovers
__________ Tie-in clamps

Cable

__________ 4/0 100-ft.
__________ 4/0 50-ft.
__________ 4/0 25-ft.
__________ 4/0 Jumper
__________ 2/0 100-ft.
__________ 2/0 50-ft.
__________ 2/0 25-ft.
__________ 2/0 Jumper
__________ 50-ft. #2 Grounding cable
__________ 50-ft. #2 Banded (three-wire plus ground)
__________ 50-ft. #2 Banded (four-wire plus ground, three-phase)
__________ Banded jumper 10-ft.
__________ 100 A 100-ft. Bates extension
__________ 100 A 50-ft. Bates extension
__________ 100 A 25-ft. Bates extension

__________ 60 A 100-ft. Bates extension
__________ 60 A 50-ft. Bates extension
__________ 60 A 25-ft. Bates extension
__________ 50-ft. stinger
__________ 25-ft. stinger
__________ Socapex 150-ft.
__________ Socapex 100-ft.
__________ Socapex 50-ft.
__________ Socapex break-out
__________ Socapex break-in

Generator

__________ 46 A EX 5500 Honda
__________ 350 A
__________ 450 A
__________ 750 A
__________ 1000 A
__________ 1200 A
__________ 1400 A

APPENDIX

Expendables checklist

H

Gel and diffusion

Orange

__________ Roll extra CTO
__________ Roll full CTO
__________ Roll Sun 85
__________ Roll 3/4 CTO
__________ Roll half CTO
__________ Roll quarter CTO
__________ Roll eighth CTO
__________ Roll full straw
__________ Roll half straw
__________ Roll quarter straw
__________ Roll eighth straw

Blue

__________ Roll extra CTB
__________ Roll full CTB
__________ Roll 3/4 CTB
__________ Roll half CTB
__________ Roll quarter CTB
__________ Roll eighth CTB

Magenta

__________ Roll full minus-green
__________ Roll half minus-green
__________ Roll quarter minus-green
__________ Roll eighth minus-green

Green

__________ Roll full plus-green
__________ Roll half plus-green
__________ Roll quarter plus-green
__________ Roll eighth plus-green

Neutral density and ND CTO

__________ ND 0.3
__________ ND 0.6
__________ ND 0.9
__________ ND 1.2
__________ 85 ND 0.3
__________ 85 ND 0.6
__________ 85 ND 0.9

Diffusion

__________ Roll 216
__________ Roll 250
__________ Roll 251
__________ Roll opal
__________ Roll grid cloth
__________ Roll light grid
__________ 1000H Velum

Other gels

__________ Other color correction (e.g., CID, SCI, Y1, Fluorofilter)
__________ Heat-shield
__________ Cosmetic colors
__________ Party colors
__________ Party gel sheets

Bulbs

3200 K

__________ PH 211 75 W (100 hours)
__________ PH 212 150 W (100 hours)
__________ ECA 500 W (60 hours)
__________ MR-16 75 W narrow spot
__________ MR-16 100 W narrow spot
__________ ECA 250 W (20 hours)

3400 K

__________ PH 213 (250 W) (3 hours)
__________ No. 1 BBA 250 W (3 hours)
__________ No. 2 EBV 500 W (6 hours)

4800 K

__________ 60 W (blue)
__________ 100 W (blue)
__________ No 1 BCA 250 W (3 hours)
__________ EBW 500 W (6 hours)

Other bulbs

__________ 75 W R-40 flood
__________ 150 W R-40 flood
__________ 300 W R-40 flood
__________ EAL 500 W R-40 flood (3200 K)
__________ 25 W Softwhite household
__________ 40 W Softwhite household
__________ 60 W Softwhite household
__________ 75 W Softwhite household
__________ 100 W Softwhite household
__________ 12″ 35 W 1613 Linestra (Osram)
__________ 20″ 60 W 1614 Linestra (Osram)
__________ 40″ 150 W 1106 Linestra (Osram)
__________ Socket 661 Linestra (Osram)
__________ 60 or 100 W blue
__________ 60 or 100 W red
__________ 60 or 100 W green
__________ 60 or 100 W clear
__________ 40 W candella base makeup table bulbs

Fluorescents

__________ 4-ft. Optima 32
__________ 4-ft. Vita-lite
__________ 8-ft. Optima 32
__________ 8-ft. Vita-lite

Tape

__________ 2″ gaffer’s tape (gray)
__________ 2″ gaffer’s tape (black)
__________ 2″ gaffer’s tape (white)

__________ Black 2″ paper tape
__________ Photo black 2″ paper tape (matte black)
__________ White 1″ camera tape
__________ Electrical tape (Bk, Bl, Rd, Gr, Wt)
__________ ½″ snot tape
__________ ¾″ snot tape

Hardware

__________ Bags clothespins
__________ Trick line (black) #4
__________ Mason line (white) #4
__________ Hanks sash cord #6
__________ Hank sash cord #8
__________ Hank sash cord #10
__________ Box large garbage bags
__________ 12″ rolls blackwrap
__________ 24″ rolls blackwrap
__________ 36″ rolls blackwrap
__________ Bottle pure isopropyl alcohol
__________ Clean lint-free rags
__________ Roll bailing wire
__________ Box cotter pins
__________ Box Sharpie markers
__________ Box pens
__________ Rubber matting (by the ft)
__________ Roll Visqueen
__________ Refracil (by the yard)
__________ Crutch tips 1¼″
__________ Crutch tips ¾″
__________ Bungee cords (36″, 24″, 18″, 12″)
__________ S-hooks

Electrical

__________ Box 20 A cartridge fuses
__________ Box 60 A fuses
__________ AA batteries
__________ 6 V meter batteries
__________ A 76 meter batteries
__________ 9 V batteries
__________ Spare Mag lightbulbs
__________ Cube taps (w/ground)
__________ Ground lifters

__________ Roll zip cord (18/2) 250′ black
__________ Roll zip cord (18/2) 250′ white
__________ Roll red/black #12 wire (twisted-pair)
__________ Roll red/black #14 wire (twisted-pair)
__________ Porcelain sockets (med. screw base)
__________ Inline taps female Edison
__________ Add-a-tap male Edison
__________ Add-a-tap female Edison
__________ Plug-in switch (Edison in/out)
__________ Hubble female Edison
__________ Hubble male Edison
__________ Box wire nuts
__________ Inline dimmers 1000 W
__________ Inline dimmers 600 W
__________ Socket dimmers (screw base)
__________ Medium screw base extension
__________ 6″ swivel screw base extension
__________ 9″ swivel screw base extension
__________ Pig nose adapters (screw base to Edison)
__________ Mogul to medium screw base adapters
__________ Medium to candella screw base adapter
__________ Candella to medium base adapter

Gels and diffusions

I

Table I.1 Kelvin Scale/MIRED Scale Conversion Table

Kelvin	0	100	200	300	400	500	600	700	800	900
2000	500	476	455	435	417	400	385	370	357	345
3000	333	323	313	303	294	286	278	270	263	256
4000	250	244	238	233	227	222	217	213	208	204
5000	200	196	192	189	185	182	179	175	172	169
6000	167	164	161	159	156	154	152	149	147	145
7000	143	141	139	137	135	133	132	130	128	127
8000	125	123	122	120	119	118	116	115	114	112
9000	111	110	109	108	106	105	104	103	102	101

Example*: To find the MIRED value for a 6500 K source, look across from 6000, and down from 500. The MIRED value is 154.*

Table I.2 Kelvin Conversion: Lee Color-Correction Conversion

	CTO (Orange)				**CTB (Blue)**			
Light Source Color (K)	***Lee 223 Eighth***	***Lee 206 Quarter***	***Lee 205 Half***	***Lee 204 Full***	***Lee 218 Eighth***	***Lee 203 Quarter***	***Lee 205 Half***	***Lee 201 Full***
2000	1901	1773	1642	1517	2075	2151	2370	2755
2300	1786	1672	1555	1443	1938	2004	2193	2519
2600	2433	2227	2024	1838	2725	2857	3257	4032
2900	2695	2445	2203	1984	3058	3226	3745	4808
3200	2959	2660	2375	2123	3401	3610	4274	5714
3500	3205	2857	2532	2247	3731	3984	4808	6711
3800	3460	3058	2688	2370	4082	4386	5405	7937
4400	3953	3436	2976	2591	4785	5208	6711	11,111
5000	4425	3788	3236	2786	5495	6061	8197	15,873
5600	4878	4115	3472	2959	6211	6944	9901	23,810
6200	5348	4444	3704	3125	6993	7937	12,048	41,667

Continued

Table I.2 Kelvin Conversion: Lee Color-Correction Conversion—cont'd.

	CTO (Orange)				CTB (Blue)			
Light Source Color (K)	*Lee 223 Eighth*	*Lee 206 Quarter*	*Lee 205 Half*	*Lee 204 Full*	*Lee 218 Eighth*	*Lee 203 Quarter*	*Lee 205 Half*	*Lee 201 Full*
6800	5780	4739	3906	3268	7752	8929	14,493	100,000
7400	6211	5025	4098	3401	8547	10,000	17,544	
8000	6623	5291	4274	3521	9346	11,111	21,277	
9000	7299	5714	4545	3704	10,753	13,158	30,303	

Table I.3 Kelvin Conversion: Rosco Color-Correction Conversion

	CTO (Orange)						**CTB (Blue)**						
Light Source Color (K)	***R-3410 Eighth***	***R-3409 Quarter***	***R-3408 Half***	***R-3411 ¾***	***R-3401 Sun 85***	***R-3407 Full***	***R-3216 Eighth***	***R-3208 Quarter***	***R-3206 Third***	***R-3204 Half***	***R-3203 ¾***	***R-3202 Full***	***R-3220 2 × CTB***
2000	1923	1845	1721	1585	1585	1499	2049	2128	2217	2315	2500	2710	4115
2300	2203	2101	1942	1770	1770	1664	2370	2475	2597	2732	2994	3300	5650
2600	2469	2342	2146	1938	1938	1812	2681	2817	2976	3155	3509	3937	7813
2900	2740	2584	2347	2101	2101	1953	3003	3175	3378	3610	4082	4673	11,364
3200	3012	2825	2545	2257	2257	2088	3333	3546	3802	4098	4717	5525	18,182
3500	3268	3049	2725	2398	2398	2208	3650	3906	4219	4587	5376	6452	34,483
3800	3534	3279	2907	2538	2538	2326	3984	4292	4673	5128	6135	7576	166,667
4400	4049	3717	3247	2793	2793	2538	4651	5076	5618	6289	7874	10,417	
5000	4545	4132	3559	3021	3021	2725	5319	5882	6623	7576	10,000	14,493	
5600	5025	4525	3846	3226	3226	2890	5988	6711	7692	9009	12,658	20,833	
6200	5525	4926	4132	3425	3425	3049	6711	7634	8929	10,753	16,393	33,333	
6800	5988	5291	4386	3597	3597	3185	7407	8547	10,204	12,658	21,277	62,500	
7400	6452	5650	4630	3759	3759	3311	8130	9524	11,628	14,925	28,571		
8000	6897	5988	4854	3906	3906	3425	8850	10,526	13,158	17,544	40,000		
9000	7634	6536	5208	4132	4132	3597	10,101	12,346	16,129	23,256	90,909		

Table I.4 Kelvin Conversion: GAM Color-Correction Conversion

Light Source Color (K)	CTO (Orange)						CTB (Blue)					
	1555 Eighth	*1552 Quarter*	*1549 Half*	*1546 ¾ CTO*	*1543 Full*	*1540 Extra CTO*	*1535 Eighth*	*1532 Quarter*	*1529 Half*	*1526 ¾ Blue*	*1523 Full*	*1520 Extra CTB*
2000	1916	1852	1721	1585	1520	1294	2037	2110	2315	2577	2703	2817
2300	2193	2110	1942	1770	1689	1414	2353	2451	2732	3106	3289	3460
2600	2457	2353	2146	1938	1842	1520	2660	2786	3155	3663	3922	4167
2900	2725	2597	2347	2101	1988	1618	2976	3135	3610	4292	4651	5000
3200	2994	2841	2545	2257	2128	1709	3300	3497	4098	5000	5495	5988
3500	3247	3067	2725	2398	2252	1789	3610	3846	4587	5747	6410	7092
3800	3509	3300	2907	2538	2375	1866	3937	4219	5128	6623	7519	8475
4400	4016	3745	3247	2793	2597	2000	4587	4975	6289	8696	10,309	12,195
5000	4505	4167	3559	3021	2793	2114	5236	5747	7576	11,364	14,286	18,182
5600	4975	4566	3846	3226	2967	2212	5882	6536	9009	14,925	20,408	29,412
6200	5464	4975	4132	3425	3135	2304	6579	7407	10,753	20,408	32,258	62,500
6800	5917	5348	4386	3597	3279	2381	7246	8264	12,658	28,571	58,824	500,000
7400	6369	5714	4630	3759	3413	2451	7937	9174	14,925	43,478	200,000	
8000	6803	6061	4854	3906	3534	2513	8621	10,101	17,544	76,923		
9000	7519	6623	5208	4132	3717	2604	9804	11,765	23,256			

Table I.5 Daylight Color Correction (CTO Gels)

Name	Rosco Cinegel	MIRED Shift	Lee	MIRED Shift	GAM	MIRED Shift	K Shift	Light Reduction (Stops)
Extra CTO	–	–	–	–	1540	+273	20,000-3200	1
							5500-2200	
Full CTO	3407	+167	204[a]	+159	1543	+163	6500-3200	
Full Straw	3441		441				5500-2900	⅔
Sun 85	3401	+131	–	–	–	–	5500-3200	⅔
85 Acrylic	3761							
¾ CTO	3411	+130	285	–	1546	130	5500-3200	⅔
½ CTO	3408	+81	205[a]	+109	1549	+81	5500-3800	⅓
½ Straw	3442		441					
½ CTO Acrylic	3751							
¼ CTO	3409	+42	206[a]	+64	1552	+40	5500-4500	⅓
¼ Straw	3443		441					
⅛ CTO	3410	+20	223[a]	+26	1555	+22	5500-4900	¼
⅛ Straw	3444		441					

[a] *Also available in 60-in. rolls.*

Table I.6 Neutral Density and ND/Daylight Correction Gels

Gel	Rosco Cinegel	MIRED Shift	Lee	MIRED Shift	GAM	K Shift	Reduction (Stops)
0.15 ND	3415	0	298	0	1514	0	½
0.3 ND Acrylic	3402 3762	0	209[a]	0	1515	0	1
0.6 ND Acrylic	3403 3763	0	210[a]	0	1516	0	2
0.9 ND Acrylic	3404 3764	0	211[a]	0	1517	0	3
1.2 ND	–	–	299	0	1518	0	4
CTO 0.3 ND	3405	+131	207	+159	1556	5500-3200	1
CTO 0.6 ND	3406	+131	208	+159	1557	5500-3200	2
CTO 0.9 ND	–	–	–	–	1558	5500-3200	3

Cinemills Corporation makes gels that share the same product numbers as Lee.
[a]Also available in 60-in. rolls.

Table I.7 Tungsten Color Correction (CTB Gels)

Name	Rosco Cinegel	MIRED Shift	Lee	MIRED Shift	GAM	Kelvin Shift (K)	Light Reduction (Stops)
Double Blue	3220	−257	200	–	–	2800-10,000	4
Extra CTB	–	−150	–	–	1520	3200-6200	1¾
Full CTB	3202	−131	201	−137	1523	3200-5700	1⅓
¾ CTB	3203	–	281	–	1526		1¼
½ CTB	3204	−68	205	−78	1529	3200-4300	1
⅓ CTB	3206	−49	–	–	–	3200-3800	⅔
¼ CTB	3208	−30	203	−35	1532	3200-3600	⅔
⅛ CTB	3216	−12	218	−18	1535	3200-3400	⅓

Cinemills Corporation makes gels that share the same product numbers as Lee.

Table I.8 Blue/Orange Correction: Colormeter LB Index (MIREDs)

Colormeter LB Reading (MIREDs)	Kodak Wratten Filter		Light Loss Due to Filter	Approximate Equivalent Gel	Kelvin Shift	
	Amber	Blue			From	To
−257	–	–	4	Double CTB	3200	10,000
−133	–	80A	2	Full CTB	3200	5500
−112	–	80B	1⅔	–	3400	5500
−100	–	80C + 82A	–	¾ CTB	3200	4700
−90	–	82C + 82C	1⅓	–	2490	3200
−81	–	80C	1	½ CTB	3800	5500
−77	–	82C + 82B	1⅓	–	2570	3200
−66	–	82C + 82A	1	–	2650	3200
−56	–	80D	⅓	–	4200	5500
−55	–	82C + 82	1	⅓ CTB	2720	3200
−45	–	82C	⅔	–	2800	3200
−32	–	82B	⅔	¼ CTB	2900	3200
−21	–	82A	⅓	⅛ CTB	3000	3200
−10	–	82	⅓	–	3100	3200
+9	81	–	⅓	–	3300	3200
+18	81A	–	⅓	–	3400	3200
+27	81B	–	⅓	⅛ CTO	3500	3200
+35	81C	–	⅓	–	3600	3200
+42	81D	–	⅔	¼ CTO	3700	3200
+52	81EF	–	⅔	–	3850	3200
+81	85C	–	⅓	½ CTO	5500	3800
+112	85	–	⅔	–	5500	3400
+133	85B	–	⅔	¾ CTO or Sun 85	5500	3200
+167	85B + 81C	–	⅔	Full CTO	5600	2900

Table I.9 Green/Magenta Correction: Colormeter CC Index

Colormeter II Color Compensation	Colormeter III		Gel Source with Gel Name	Rosco Cinegel No.	Lee Gel No.	GAM Gel No.	Compensation in f-Stops	Conversion
	CC Filter Magenta	CC Filter Green						
+18	40M	–	–	–			⅔	Removes green
+13	30M	–	Full Minus Green	3308	247	1580	⅔	Removes green
+8	20M	–	–	–			⅓	Removes green
+6	15M	–	Half Minus Green	3313	248	1582	⅓	Removes green
+4	10M	–	–	–	–	–	⅓	Removes green
+3	7.5M	–	¼ Minus Green	3314	249	1583	⅓	Removes green
+2	5M	–	–	–	–	–	⅓	Removes green
+1	3.5M	–	⅛ Minus Green	3318	279	1584	¼	Removes green
−1	–	3.5G	⅛ Plus Green	3317	278	–	¼	Adds green
−2	–	7.5G	¼ Plus Green	3316	246	–	⅓	Adds green
−4	–	10G	–	–	–	–	⅓	Adds green
−5	–	15G	½ Plus Green	3315	245	1587	⅓	Adds green
−7	–	20G	–	–	–	–	⅓	Adds green
−10	–	30G	Full Plus Green	3304	244	1585	⅔	Adds green
−13	–	40G	–	–	–	–	⅔	Adds green
–	30M	–	Fluoro-Filter	3310	–	1590	1⅔	Converts cool whites to 3200 K
–	–	30G	Plus-green 50	3306	–	–	1¼	Converts 3200 K source to match cool whites
–	–	30G	Fluorescent 5700	–	241	–	1⅔	Converts 3200 K source to 5700 K (cool white fluorescents)
–	–	30G	Fluorescent 4300	–	242	–	1½	Converts 3200 K source to 4300 K (white fluorescents)
–	–	30G	Fluorescent 3600	–	243	–	1¼	Converts 3200 K source to 3600 K (warm white fluorescents)

Minolta Colormeter II and earlier read out + or − color compensation index number (first column). Newer models read out in CC filter numbers (second and third columns).

Table I.10 Diffusion Materials

Types of Diffusion	Product No.	Light Reduction	Notes
Lee			
Full Tough Spun	214	2½	Slight softening of field and beam edge
Half Tough Spun	215	1½	Slight softening of field and beam edge
Quarter Tough Spun	229	¾	Slight softening of field and beam edge
Full Tough Spun	261	2	Flame retardant. Slight softening of field and beam edge
¾ Tough Spun	262	1⅔	Flame-retardant
½ Tough Spun	263	1⅓	Flame-retardant
⅛ Tough Spun	264	1	Flame-retardant
¼ Tough Spun	265	¾	Flame-retardant
216 White Diffusion	216	1½	Very popular moderate/heavy diffusion. Available in 60" width
½ 216	250	¾	Moderate beam spread and softening
¼ 216	251	⅓	Moderate beam spread and softening
⅛ 216	252	⅛	Moderate beam spread and softening
Blue Diffusion	217	1½	Increases color temperature very slightly
Daylight Blue Frost	224	2 ¼	CTB frost
Neutral Density Frost	225	2	ND 0.6 frost
Brushed Silk	228	¾	Diffuses light in one direction only
Hampshire Frost	253	¼	Very light frost
New Hampshire Frost	254	–	High-temperature polycarbonate base
Hollywood Frost	255	–	–
Half Hampshire	256	–	–
Quarter Hampshire	257	–	–
Heavy Frost	129	1⅓	Flame-retardant
White Frost	220	1⅓	Flame-retardant
Blue Frost	221	1⅓	Flame-retardant. Increases color temperature very slightly
Grid Cloth	430	–	Heavy white fabric in 52 in. width
Light Grid Cloth	432	–	Lighter white fabric in 52 in. width

Continued

Table I.10 Diffusion Materials—cont'd.

Types of Diffusion	Product No.	Light Reduction	Notes
Rosco			
Tough Spun	3006	2½	Slight softening of field and beam edge
Light Tough Spun	3007	1⅔	Slight softening of field and beam edge
¼ Tough Spun	3022	1	Slight softening of field and beam edge
Tough Frost	3008	2	Slight to moderate softening, moderate beam Spread but with discernible beam center
Light Tough Frost	3009	1½	Slight to moderate softening, moderate beam spread but with discernible beam center
Opal Tough Frost	3010	1	Popular light diffusion with slight to moderate softening, moderate beam spread but with discernible beam center
Light Opal	3020	½	Slight to moderate softening, moderate beam spread but with discernible beam center
Tough White Diffusion	3026	3½	Like Lee 216. Dense diffusion with wide beam spread creating even field of shadowless light
½ White Diffusion	3027	2½	Like Lee 250. Moderately dense diffusion with wide beam spread
¼ White Diffusion	3028	1½	Like Lee 251. Moderate diffusion with wide beam spread
Tough Rolux	3000	2½	Moderately dense diffusion with wide beam spread
Light Tough Rolux	3001	–	Moderate diffusion with wide beam spread
Grid Cloth	3030	5	Comes in 54-in. rolls. Very dense diffusion with very wide beam spread, which creates soft shadowless light. Ideal for large area diffusion. Not tolerant of high heat
Light Grid Cloth	3032	3½	Smaller weave than grid cloth. Considerable softening. Comes in 54-in. rolls
¼ Grid Cloth	3034	2½	Considerable softening. Comes in 54-in. rolls
Silent Frost	3029	3	Diffusion made of a rubbery plastic that does not crinkle and rattle in the wind
Hilite	3014	1	Quiet like silent frost. Comes in 54-in. rolls
Soft Frost	3002	2	Quite like silent frost, denser than Hilite
Wide Soft Frost	3023	2	In 72 in. width
½ Soft Frost	3004	½	Quiet, light diffuser
Tough Silk	3011	1½	Considerable softening in one direction only
Light Tough Silk	3015	1	Considerable softening in one direction only
Tough Booster Silk	3012	–	Raises color temperature from 3200 to 3500 K with silk softening characteristics

Tough Booster Frost	3013	–	Raises color temperature from 3200 to 3800 K with frost softening characteristics
Full Blue Frost	3017	–	Raises color temperature from 3200 K to daylight with frost softening characteristics
GAM—The Great American Market			
Medium GAM Frost	10	–	Soft light, warm center, diffuse edge
Light GAM Frost	15	–	Soft light, warm center, diffuse edge
Full GAM Spun	32	2½	Textural, warm center defined edge
Medium GAM Spun	35	1⅔	Textural, warm center defined edge
Light GAM Spun	38	1	Textural, warm center defined edge
Gamvel	45	3	Soft light with diffuse shadow line
216 GAM White	55	–	Shadowless, white light. Heavy diffusion with no center or edge visible
Medium GAM Silk	65	–	Spreads light predominantly in one direction
Light GAM Silk	68	–	Spreads light predominantly in one direction
Gam Fusion	10-10	¼	Almost clear with no color shift
Gam Fusion	10-20	¼	Very light diffusion with no color shift
Gam Fusion	10-30	½	Light diffusion with no color shift
Gam Fusion	10-40	½	Medium-light diffusion with no color shift
Gam Fusion	10-50	1	Medium diffusion with no color shift
Gam Fusion	10-60	2	Medium-heavy diffusion with no color shift
Gam Fusion	10-70	5	Heavy diffusion with no color shift
Gam Fusion	10-75	5	Heavy diffusion with no color shift
Gam Fusion	10-80	6	Very heavy diffusion with no color shift
Gam Fusion	10-90	6	Fully diffuse with no color shift

Light reduction values given here are manufacturers' approximate figures. The actual transmission will depend on the beam angle of the light and the distance from the diffusion.

Glossary*

Φ phase.
Ω resistance (ohms).
18% gray medium gray used to determine exposure.
216 a popular, relatively heavy diffusion.
4-by cart a cart for moving and storing 4 × 4-ft. frames, flags, nets, bounce boards, and so on.
4-by floppy a 4 × 4-ft. flag with an additional flap that folds out to make a 4 × 8-ft. flag.
A ampere.
Abbott a manufacturer of single-conductor connectors sometimes used on feeder cable.
Abby Singer the second-to-last shot of the day. The shot before the *martini*.
Above-the-line costs production costs of the producer, director, writer, and principal actors.
AC (1) Alternating current. (2) Camera assistant.
Ace a 1k Fresnel light.
AD *see* assistant director.
Adapter a device used to convert from one type of connector to another.
Aerial lift one of a variety of different lifts or telescoping boom arm vehicles commonly used as a high lighting platform for large exterior shots. Commonly called a Condor or Snorkelift, which are trade names.
AFHSS adaptive frequency hopping spread spectrum. A method used by wireless DMX systems to increase signal reliability and reduce interference with other transmissions. A matched transmitter and receiver simultaneously hop in a quasi-random way between frequencies in a given range.
Alternate start code a feature of the DMX512-A standard that expands the protocol to allow the DMX512-A signal to be used for communications other than just DMX values, including two-way communications.
Ammeter a test meter for measuring amperage.
Ampacity of cable, the amperage capacity that the cable can carry continuously (as defined by the NEC).
Amperage (*I*) a unit of current. One ampere will flow through a resistance of 1 Ω under a pressure of 1 V.
Ampere-hour a quantity of electricity equal to the number of amperes times the number of hours of charge that a battery can deliver.
AMPTP alliance of motion picture and television producers.
Anode a negative electrode.
ANSI American National Standards Institute. Three-letter ANSI codes are used to identify light bulbs (e.g., EGT is a 1k bulb). Specifications for lighting control networks such as DMX512-A are also ANSI standards.
Apple box a reinforced plywood box used on the set for many purposes, including to raise an actor who is too short or to raise furniture. Apple boxes come in four sizes: full, half, quarter, and *pancake*.
Arc light any light that makes light by forming an arc, including arc discharge lights such as HMIs. On the set, *arc light* is normally understood to mean a carbon arc light.
ASA (1) American Standards Association (now the ANSI). (2) The exposure index (EI) rating of a film emulsion, also referred to as ISO.
Aspect ratio the ratio of the width to the height of the film frame. The standard aspect ratios are 1.33:1 (NTSC television, commonly referred to as 4 × 3), 1.66:1 (European theatrical film standard), 1.78:1 (high-definition television, commonly referred to as 16 × 9), 1.85:1 (American theatrical film standard), and 2.36:1 (Anamorphic 35 mm).
Assistant director (AD) the person who runs the set. The AD is responsible for coordinating the actions of the many departments so that everyone is ready when the time comes to roll cameras.

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*Entries that have an asterisk are taken from *Practical Electrical Wiring* by Herbert P. Richter and W. Creighton Schwann. New York: McGraw-Hill, 1990.

AVR automatic voltage regulator.
AWG American Wire Gauge.
Baby stand a stand with a ⅝-in. pin.
Baby pin a ⅝-in. mounting pin that mates with a ⅝ in. receptacle.
Baby a 1k Fresnel lighting fixture manufactured by the Mole-Richardson Co.
Backdrop a scenic painting or enlarged photograph transparency used outside set windows and doors when filming in a studio.
Bail U-shaped part of a lighting fixture that attaches the fixture to the stand.
Ballast a power supply required to operate any discharge light, such as HMI, fluorescents, and xenon lights. The ballast provides the ignition charge and then acts as a choke, regulating the power to maintain the arc.
Banded cable several single-conductor cables banded together at intervals, forming one bundle.
Barn doors metal shields on a ring that mounts to the front of a lighting fixture. Barn doors are used to shape and control the beam of light.
Base (1) The basket on the underside of a fixture. (2) The base of a bulb is the porcelain part. (3) The lamp socket is also sometimes called the *base*.
Bates a common name for Stage Pin connectors—three-pin connectors in sizes from 20 to 100 A.
Batten usually refers to 1 × 3-in lumber. May also refer to pipe on which lights, scenery, curtains, blacks, and borders can be hung.
Battery belt a battery pack, usually containing rechargeable batteries, mounted in a belt that can be worn around the waist during mobile shooting.
Bead board styrofoam used to make soft bounce light.
Beam angle the diameter of the beam angle is defined as the area of the light field that is 50% or more of the peak intensity of the beam.
Beam projector a type of lighting fixture that employs a large parabolic mirror reflector to create relatively strong, parallel rays of light.
Beaver board a nail-on plate mounted to a *pancake*.
Below-the-line costs the production costs of all members of the crew but not the producer, director, writer, and principal actors.
Best boy the assistant chief lighting technician. The best boy is the gaffer's administrative assistant.
Big eye a 10k incandescent fixture with an extra large lens (Mole-Richardson).
Black body locus the black body locus is the curved line of points on a chromaticity diagram, defined by the color points of a black body radiator when heated at a range of temperatures. The locus represents different color temperatures (shades of white light) from orange to blue.
Black wrap a thick, durable black foil used on hot lights to control spill and to shape the beam.
Blackbody radiator a theoretical continuous spectrum light source used in defining the concept of color temperature. In order to give us a fixed reference point, the color makeup of any source can be compared to that of a theoretical "perfect black body radiator" when it is heated.
Blonde an Ianero 2k open-face fixture.
Boom operator the sound person who operates the microphone boom and affixes microphones to the talent.
Branch circuit as defined by the NEC, circuits that are downstream of the last overcurrent protection.
Branchaloris a branch of a tree or bush held in front of a light to create a moving or stationary foliage pattern.
Broad a nonfocusing, wide-angle lighting fixture, typically using a double-ended bulb, installed in a rectangular fixture with a silver reflector.
Brute a 250-A carbon arc light manufactured by Mole-Richardson, Co.
Bull switch a main switch used on the main feeder or on subfeeder lines.
Bump a feature on a dimmer console—an instantaneous change in stage levels from one set of intensities ("look") to another.

Buss bar copper bars in distribution equipment, such as spider boxes, to which lug connectors are attached. Buss bars more generally are the copper bars within any piece of electrical equipment, especially distribution equipment, that provide a junction point.

Butterfly set a frame used to support a net or silk over the top of the action. The silk reduces and softens direct sunlight.

C Celsius (temperature scale).

C-47 a common, wooden spring-type clothespin.

Cable crossover a special ramp used to protect cable from being damaged by being run over and to protect pedestrians from tripping over cable.

CAD computer aided design, a type of computer software used for drafting scale drawings. The lighting department uses this software for drafting light plots.

Call sheet a sheet distributed by the production department before the end of each day that indicates the scenes to be shot on the following day, the call time of all cast and crew members, special travel instructions, special equipment that will be used, and general notices to the cast and crew.

Cam-Lok a type of single-conductor connector used for feeder cable.

Can a permanently installed panelboard bus bar in a soundstage.

Candela (cd) a unit of light intensity derived from brightness and distance. $cd = FC \times ft^2$ or, in Europe, $cd = lux \times m^2$.

Carbon arc light a very bright DC lighting fixture that creates light by igniting an arc flame between two carbon electrodes.

CAT 5 cable high-speed digital communication cable commonly used for computer networks; also sometimes used for DMX512 networks.

Cathode a positive electrode.

Catwalk a metal or wooden walkway above a soundstage.

CC *see* color compensation.

C-clamp a large C-shaped clamp with a baby stud or junior receptacle welded to it that is used to mount lights to beams.

CCT correlated color temperature. The equivalent color temperature of a light source that does not have a continuous spectrum (such as HMI, fluorescent or LED).

Celo cuke a wire mesh painted with a random pattern and placed in front of a light to throw a subtle pattern.

Chain vice grip a mounting device that uses a bicycle chain and vice grip to create a tight clamp around pipes, poles, or tree limbs.

Channel device controlling a dimmer or group of dimmers. In a simple system, there is a slider for each channel. On most current control systems, channels are numbers, accessed by a numeric keypad. Multiple dimmers may be controlled by a single channel to which they are *patched.*

Chaser lights a linear string of lights similar to those on a theater marquee. The lamps are wired in three, four, or five circuits; equally spaced lights are connected to the same circuit, which can be sequentially energized, creating the effect of light chasing along the line of lights.

Cheater an Edison plug adaptor that allows three-prong grounded plugs to be plugged into a two-prong ungrounded outlet found in older buildings. Also called a *ground lifter*, *ground plug adaptor*, or *two-to-three adaptor*.

Chiaroscuro a strongly contrasting treatment of light and shade in drawing and painting. Translated from the Italian, the word means "half-revealed."

Chicken coop an overhead suspended light box that provides general downward ambient or fill light. Also called a *coop*.

Chief lighting technician *see* gaffer.

Chimera a specially designed, lightweight, collapsible soft box manufactured by Chimera Photographic Lighting.

CID *see* compact indium discharge.

CIE chromaticity diagram the CIE 1931 chromaticity diagram is a commonly used model representing every color perceived by the human eye. The International Commission on Illumination (CIE) first defined human perception of color mathematically in a 1931 study. This definition is known as the CIE 1931 XYZ color space.

Cinevator stand a heavy-duty stand used for the largest types of lights. The mechanism that raises and lowers the light is driven by an electric motor.

Circuit breaker an overcurrent protection switch. It trips and disconnects a circuit if the current drawn exceeds the rating of the circuit breaker.

Circuit (1) When talking about dimmer circuits, refers to everything downstream of the dimmer, from the dimmer's output connector to the lighting fixtures themselves. (2) Generally, an electrical circuit is one that has a continuous path from the power source, through the load and back to the power source.

cmil cross-sectional area of cable in circular mil.

Color chart a chart of standard colors filmed at the head of a roll of film as a color reference for the lab.

Color compensation (CC) a reading gained from a color meter indicating the amount of green or magenta gel needed to neutralize off-color hues, such as in fluorescent lights.

Color space in the case of a display or RGB light fixture, the device uses three or more illuminated colors in combination to create an array of colors. If the color points of three illuminants (red, green, and blue for example) are plotted on a chromaticity diagram, the triangle formed includes all the colors that are achievable by the device. Any colors outside this triangle cannot be achieved. In the case of cameras, the color space is defined by the colors achievable by the three color sensors (video) or emulsion layers (film).

Color temperature a temperature expressed in Kelvin (K) that defines the color makeup of light emitted by a source, such as the sun or a filament lamp, that has a continuous color spectrum.

Combo stand a junior stand with a 1⅛-in. receptacle used to hold reflector boards and larger lights.

Compact indium discharge (CID) a 5500 K gas discharge globe often used in sun guns.

Compact source iodine (CSI) a type of gas discharge bulb similar to an HMI.

Condor a vehicle with a telescoping boom arm used as a platform to position lights 30–120 ft in the air.

Continuity tester a device that runs a small amount of voltage through a conductor and lights an indicator or makes a sound if the conductor is continuous.

Continuity (1) Electrical continuity: the unbroken flow of electricity through a conductor or lamp filament. (2) Script continuity (the job of the script supervisor): the task of making sure that all the details of the scene remain consistent from take to take and from angle to angle. Shots may be filmed hours and even weeks apart, but they will be cut back to back in the final film.

Continuous load as defined by the NEC, an electrical load that is to be delivered continuously for more than 3 hours.

Continuous spectrum the color makeup of light from a source, such as an incandescent bulb or natural daylight, which includes all the wavelengths of light without spikes or holes anywhere across the spectrum of colors.

Contrast ratio the ratio of the intensity of the key light plus the fill light to the intensity of the fill light alone.

Control console a computerized controller that provides a user interface and generates a control signal to transmit data to devices on a lighting control network, such as a DMX512.

Coupler a clamp that closes around pipe commonly used to hold one pipe to another pipe at right angles, or at adjustable angles. Couplers are also commonly used to attach moving light fixtures to pipe or truss.

Crank-up stand a heavy-duty stand that provides a crank to raise and lower heavy lights.

CRI color rendering index.

Cribbing blocks of wood used to level dolly track.

Croney cone a cone-shaped attachment fitted with diffusion that fits on the front of a light to soften and control the beam.

Cross-fade a fade that contains both an up-fade and down-fade. Also may refer to any fade where the levels of one cue are replaced by the levels of another cue.

Crowder hanger a fixture mount that fastens to the top of a set wall and provides two studs.

Crystal-controlled a crystal-based circuit that maintains a camera's frame rate very precisely. A wild camera has no crystal control.

CSI *see* compact source iodine. A type of arc lamp.

C-stand a multipurpose stand used for setting flags and nets. Short for *Century stand.*

CTB gel a blue gel that corrects a tungsten source to daylight.

CTO gel an orange gel that corrects a daylight source to tungsten.

Cube tap a device that allows three Edison plugs to plug into one Edison socket.

Cucaloris a wooden cutout pattern placed in front of a light to create a pattern.

Cue light a flashing or rotating light positioned outside the set to warn people when the camera is rolling.

Cue the process of recalling *a preset* from its memory location (in a control console) and putting the result on stage.

Cup blocks wooden blocks with concave indents. Cup blocks are placed under the wheels of light stands to prevent them from rolling.

Current the rate of flow of electricity measured in amperes.

Cutter a long, thin flag used to make cuts in the light.

Cyc strip a strip of open-face fixtures used to light a cyclorama. The lights are often wired in two, three, or four separate circuits to provide individual control of different colors.

Cyclorama a seamless hanging or set piece, usually white, often curved where it meets the floor. It is used to create a limbo background, having no discernible horizon or texture.

Day rate the wage for a day's work.

Daylight light commonly considered to have a color temperature of 5500-6000 K. Daylight-balanced film renders colors naturally when lit with 5600 K light.

DC *see* direct current.

Dead-man pedal a floor pedal that must be pressed by the operator's foot to operate or drive an aerial lift. The dead-man pedal is a safety device to prevent runaways.

Dedolight a small, special light fixture with a wide range of beam angle adjustment.

Delta-connected system a three-phase configuration of coils at the power source (either a generator or transformer). The transformer coils are commonly depicted as a triangle (delta).

Depth of field the depth of the scene that will be in focus on the screen. Depth of field varies with the camera's aperture, focal length, and distance from the subject and the film format.

Deuce board an AC/DC distribution box having high-amperage contactors that can be controlled from remote switches.

Deuce a 2k Fresnel light.

Dichroic filter a coating that can be applied either to a glass filter or a reflector that colors the light by selectively passing wavelengths. Dichroic filters are available in many colors, including color correction.

Die the semiconductor chip of an LED.

Diffusion material used in front of lighting fixtures to soften the light.

Dimmer the device controlling power to a circuit and lighting fixtures. Two lights on one dimmer circuit cannot be separately controlled.

Direct current (DC) current that does not alternate polarity. Batteries create DC.

Director of photography (DP) the cinematographer in charge of the lighting and camera departments. The DP has direct creative control of the image.

Discontinuous spectrum a light source with a discontinuous spectrum, such as a standard fluorescent bulb, that does not emit light evenly across the color spectrum, but instead has spikes at particular wavelengths and emits little or no light at others.

Distant location a location that is far enough from the production's town of origin that the crew must stay overnight.

Distribution box an electrical box with circuit protection, used to step down cable size and connector size and provide a variety of sizes of outlets for subfeeders, extensions, and various sizes of lights.

DMX512 data link the connection point of the DMX512 signal cable to a controller. Each data link supplies one universe (512 slots) of data, refreshed 44 times/second. For DMX512, this is commonly a 5-pin XLR connector, but modern controllers also use RJ-45 connectors for either DMX512 or Ethernet communications.

DMX512 Universe a DMX512 universe comprises 512 sequential data slots. A universe is sometimes thought of as a single DMX512 data link, and all devices connected to it.

DMX512 lighting control network protocol.

Dog collar a short length of aircraft cable used to secure lights hung above the set. The collar is fitted with a loop at one end and a leash clip or carabiner at the other.

Doorway dolly a small, steerable flatbed dolly with large inflated tires, frequently used to move cable and large lights.

Dot a very small, circular flag, net, or silk used to alter only a small portion of the beam of light.

Douser the mechanism on a follow spot used to make a quick blackout without the operator having to extinguish the light itself. On a carbon arc follow spot, the douser protects the lens while the arc is struck.

Down-fade the portion of a fade that involves only channels that are decreasing in level.

DP *see* director of photography.

Dress a light to neaten up the light or cable.

Duck bill a vice grip with a baby stud on the handle and two 6 sq. in. plates welded to the jaws. Used to mount foamcore and bead board on a C-stand.

Dummy load *see* ghost load.

Duvetyn thick, black cloth used to block light.

E electromotive force, measured in volts.

Ears the metal brackets on the front of a light that hold the barn doors and scrims.

Edison plug and socket a typical household plug and socket with two parallel blades and a U-shaped grounding pin. Also called a *U-ground parallel-blade plug*.

Egg crate an accessory for a soft light fixture that cuts stray light and narrows the beam angle.

EIA-485 a standard for the electrical specifications of digital signal transmission, which was incorporated into the DMX standard at its genesis.

Electrician common name for a lighting technician.

Electromotive force voltage.

Electronic ballast a solid-state ballast. The term *electronic ballast* is synonymous with flicker-free square-wave ballast (HMI) or high frequency (fluorescent).

Ellipsoidal reflector spotlight (ERS) a spotlight of fixed or adjustable focal length that has framing shutters and a projection gobo slot and produces a long, narrow throw of light. Also called a *Leko*.

Elvis a gold lamé stretched on a frame and used to bounce light.

Emulsion the photochemical substance on a piece of film that captures the image.

Equipment grounding the grounding of noncurrent-carrying parts of equipment via a green grounding wire.

ESTA the Entertainment Services and Technology Association, responsible for many initiatives within in the entertainment industry, including developing DMX512-A as an ANSI standard and other forward thinking standards for control networks, as well as publishing technical and safety reports and creating certification testing for entertainment electricians, among other things.

Ethernet a high-speed network protocol designed for communication between computers and devices, also used in lighting control.

Expendables supplies, such as tape, that are used up during the course of a production.

Eye light a light used to create a twinkle of light in the eye of the subject.
F Fahrenheit (temperature scale).
Fade a gradual change in stage levels from one set of intensities ("look") to another.
Fall-off the diminishing intensity of light from one position to another.
FAR a lighting fixture that lights a cyclorama.
FAY an incandescent par light with dichroic coating that creates daylight-colored light.
FC *see* foot-candle.
Feeder cable large single-conductor cable used to run power from the power source to the set.
Field angle the angle from the light fixture to the opposite edges of the field.
Field the area that is at least 10% of the maximum candle power of a beam of light.
Filament the tungsten coil inside a bulb that glows when voltage is applied to it, creating light.
Fill light soft light used to reduce the darkness of the shadow areas.
Finger a very small rectangular flag, net, or silk used to make minute cuts of the beam of light.
First team the director and actors.
Fixture a luminaire, light, lamp, instrument, head, or lantern.
Flag black duvetyn cloth stretched over a metal frame and used to shape and cut light.
FLB filter a filter used on the camera to remove the green hue of fluorescents.
Flex arm a small jointed arm used to hold fingers and dots.
Flicker box an electrical circuit box used to simulate the flickering of a flame or television screen. A flicker box randomly increases and decreases the intensity of the lighting fixtures.
Flicker-free an HMI or fluorescent ballast that provides a square-wave or high-frequency output that eliminates light-level pulsation when filmed at any shutter speed.
Flood the spread of the beam from a fixture that is broad and relatively weak.
Foamcore a white, glossy card laminated to ¼-in. Styrofoam and used to bounce light.
Focal length the distance from a lens at which an image comes into focus (the focal point). For camera lenses, it is usually expressed in millimeters. A long lens has a very narrow angle of view and a short depth of field. A short lens has a wide angle of view and greater depth of field.
Focal spot an accessory that mounts on a Fresnel fixture, essentially changing the fixture into an ellipsoidal spotlight.
Follow spot a high-power, narrow-beam spotlight suitable for very long throws. It is designed to follow performers on stage.
Foot-candle (FC) an international unit of illumination. One foot-candle equals the intensity of light falling on a sphere placed 1 ft. away from a point source of light of one candela. One foot-candle equals one lumen per square foot. *See also* lux.
Foot-lambert an international unit of brightness. One foot-lambert equals the uniform brightness of a perfectly diffusing surface emitting or reflecting light at a rate of one lumen per square foot.
Forced call when less than the minimum turnaround time is given between wrap on one day and call on the following day.
Format the film or video medium and the aspect ratio of the image.
Forward phase dimmer a dimmer technology that uses an SCR or triac circuit to control the duty cycle within each half cycle of the AC sinewave, using a pulse-width-modulated signal from the control electronics.
fps frames per second.
Framing shutters in an ellipsoidal spotlight, or on some profile moving lights, shutters that can be adjusted to cut the beam and shape it in geometric shapes.
Frequency the number of cycles/second of alternating current, measured in Hertz.
Fresnel (1) a type of lens that has the same optical effect as a plano-convex lens but has reduced weight and heat retention. (2) The light fixture that uses a Fresnel lens.

f-stop a scale used to set the aperture of the camera.
Furniture clamp an adjustable clamp used for mounting lights.
Furniture pad a packing blanket used to protect floors, deaden sound, soften a fall, and so on.
Fuse an overcurrent device that uses an alloy ribbon with a low melting point. The circuit is broken when the current exceeds the rating of the fuse.
Gaffer the head of the lighting crew. The gaffer works directly under the director of photography.
Gaffer's tape heavy, fabric-based tape that rips cleanly in the direction of the weave. It is used for securing cables and lights on the set.
Gamma a graph line that describes a film emulsion's reaction to tonal gradation and its innate contrast. Also called *D log E curve* or *characteristic curve*.
Gang box an outlet box that provides Edison outlets and plugs into a larger connector, such as a 60 A Bates or a 100 A stage box.
Gator grip a baby stud on a spring-loaded clamp with rubber jaws, used for mounting lightweight fixtures to doors, poles, furniture, and so on.
Gel polyester-based colored gelatin used to color a beam of light.
Generator the power plant used to create power on location. Motion picture generators are sound-baffled and provide bus bars or other common feeder connectors.
Genny *see* generator.
GFCI, GFI *see* ground fault circuit interrupter.
Ghost load a load not used to light the set and placed on a circuit to balance the various legs of power or to bring the load on a resistance-type dimmer up to its minimum operating wattage. Also called *dummy load* and *phantom load*.
Globe a bulb.
Gobo arm the arm of a C-stand.
Gobo head the metal knuckle that attaches the gobo arm to a C-stand.
Golden time premium overtime pay after 12 hours of work (14 hours when on a distant location). Golden time is normally double the regular hourly rate.
Gray scale a chart showing gradations of gray from white to black.
Greens the wooden catwalk suspended above the set in a sound stage.
Grid (1) A transformer unit used with a carbon arc light. (2) The structure of metal pipes suspended above the stage floor for hanging lighting fixtures.
Grid clamp a clamp that attaches to grid pipe.
Grid cloth a white nylon diffusion fabric with a gridlike weave.
Griffolyn nylon-reinforced plastic tarp material. Griffolyns are typically black on one side and white on the other; they are used as a bounce for fill. Also called *griff*.
Grip a crew member responsible for many of the nonelectrical aspects of lighting and rigging and for the camera dolly and other camera platforms.
Grip clip a metal spring clamp.
Grip helper a metal arm that mounts to a junior stand. A gobo head angles down and out from the stand to which a 4-by frame can be attached in front of the fixture.
Grip truck the truck that houses the lights and grip equipment during location shooting.
Grounded wire the grounded, white, current-carrying wire of an AC circuit. Do not confuse this term with the green *grounding wire*.
Ground fault circuit interrupter (GFCI) a special type of circuit protection required around water, pools, and in wet locations, that detects leakage current—current not returning to the power source that could pose a hazard.
Grounding wire the green, noncurrent-carrying equipment grounding wire of an AC circuit.

Ground lifter *see* cheater.
Ground row cyclorama lights placed along the ground at the base of the cyc. A mask normally hides the lights from view.
Halogen cycle the cycle by which halogen in a bulb returns tungsten deposits to the filament, preventing blackening on the inner wall of the bulb.
Head cable the cable running from the ballast of a lighting fixture to the head.
Head a light fixture.
Hi boy an extra tall stand.
HID high-intensity discharge. A type of street lamp.
High key a bright lighting style with low contrast and bright highlights.
High leg the 208 V leg of a delta-connected three-phase system.
High roller an extra tall rolling stand, often used to fly an overhead frame.
HMI *see* mercury (Hg) medium-arc iodide. Trade name of Osram's metal halide arc lamps.
Honey wagon the trailer that houses the lavatories used when shooting on location.
Hot spot (1) The beam center. (2) A shiny spot or glare reflection that is distracting to the eye.
House lights the permanent lighting in the audience area of a theater or sound stage.
Housing the metal casing that surrounds the bulb and reflector of a lighting fixture.
Hz Hertz (cycles/second).
I current, measured in amperes.
IA, IATSE International Alliance of Theatrical and Stage Employees.
IBEW International Brotherhood of Electrical Workers.
IGBT insulated gate bipolar transistor. A high-speed switching transistor circuit used to control power in various devices including HMI electronic ballasts, reverse phase dimmers, and sine-wave dimmers.
Impedance (*Z*) a measure, in ohms, of the opposition to current flow in an AC circuit. Impedance includes resistance, capacitive reactance, and inductive reactance.
Incandescent any type of electric light that creates light by making a metallic filament (usually tungsten for film lights) glow by applying current to it.
Incident light meter a light meter that reads the light falling onto the face of the meter.
Inductance a measure, in henrys, of the opposition to current change in an AC circuit (causing current to lag behind voltage). Inductance is exhibited by turns of wire with or without an iron core.
Infrared (IR) wavelengths above the highest visible wavelength of light, felt as heat.
Ingress Protection, International Protection Rating (IP) the IP rating signifies the degree to which an enclosure can protect against ingress of water, solid objects and particulates. The Commission Electrotechnique International (IEC), the body responsible for international electrical standards, created an International Protection (IP) rating standard.
Instrument a lighting fixture.
Intermittent duty operation for alternate intervals of load, no load, and rest.
Inverter an electronic device that converts DC power into AC.
IR *see* infrared.
Iris the mechanism on a follow spot that adjusts the diameter of the beam.
ISO the exposure index (EI) rating of a film emulsion.
Jockey boxes metal storage containers on the underside of a truck. Jockey boxes usually store cable, distribution boxes, and so on.
Juicer a set lighting technician.
Junior a 2k Fresnel fixture.
Junior stand a stand with a 1⅛-in. junior receptacle.
Junior stud A 1⅛-in. stud.

K Kelvin (temperature scale). Used to define the color temperature of light.
k one thousand.
Kelvin a unit of measurement of temperature (0 K = −273 °C). In set lighting, the term refers to the color temperature (color makeup) of light and not to its physical temperature.
Key light the main source lighting the subject.
Kicker a side backlight.
Kick-out the accidental unplugging of a light.
Kit rental an additional fee a technician charges for the use of his or her own tools, equipment, and hardware. Also called *box rental*.
Layout board cardboard sheets, 4 × 8 ft., commonly used to protect floors.
LED light emitting diode. A solid-state illumination engine.
Leko Leko is a trademark of Strand's ellipsoidal reflector spotlight.
Light plot a drawing depicting the layout of the lights and lighting positions.
Light-balancing (LB) scale scale used in color meters.
Lithium-ion (Li-ion) a type of rechargeable battery chemistry. Characteristics: no "memory" problems, fast charging, high sustained voltage, high cell voltage, very light weight, environmentally friendly.
Louvers thin, parallel strips with a black finish arranged in a grid pattern that is placed in front of a soft light source. Louvers reduce spill light and direct the light in one direction.
Low boy a very short stand.
Low key a dark, shadowy lighting style.
Lug an extremely heavy-duty brass connector that bolts feeder cables to bus bars, deuce boards, and spiders. Also called *sister lugs*.
Lumen a unit of light (flux).
Lumen maintenance the scheme used to define the end of the useful life of an LED, expressed as a percentage of the LEDs initial output.
Luminaire a light fixture.
Lux an international unit of light intensity used primarily in Europe. One lux equals one lumen per square meter. One foot-candle equals 10.764 lux. lux = cd/m^2.
MacAdam ellipse a MacAdam ellipse defines the distance at which two colors that are very close to one another first become distinguishable to the human eye as different colors. When plotted on a CIE chromaticity diagram, this radius is elliptical.
MacBeth a blue glass conversion filter used on some open-face lights. Converts tungsten sources to daylight.
Mafer clamp an all-purpose grip clamp (cam screw tightening) that can receive a number of different mounting attachments, such as a baby stud or a flex arm.
Magic hour the hour of light after sunset, during which the western sky creates a warm-colored soft light.
Make first, break last a rule of thumb when connecting single-conductor cables. The grounding connection must be made first, before any of the other wires. When disconnecting the cables, the grounding wire connection should be broken last.
Martini the last shot of the day.
Matth pole A pole that braces against two opposite walls to provide a structure from which to hang a lightweight fixture.
Meal penalty the fee paid by the production company (on union films) when shooting continues beyond 6 hours without breaking for a meal.
Meat ax an arm mounted to the pipe of a catwalk or to the basket of a boom platform that provides a way to place a flag in front of a fixture.
Media server a computer used to store, manipulate, and play back images and video through a projector or display.

Meltric a five-pin, heavy-duty connector used in some power distribution systems.
Memory on a dimmer console, the storage location for preset information
Mercury medium-arc iodide (HMI) a type of gas discharge bulb with a color temperature of 5600 K and high efficiency of more than 90 lumens/W.
Mickey a 1k open-face fixture manufactured by Mole-Richardson.
Midget a 200 W wide-beam Fresnel fixture manufactured by Mole-Richardson.
Mini (1) A 100 or 200 W Fresnel fixture manufactured by Mole-Richardson, or a miniature soft light manufactured by LTM. (2) Minnie: Girlfriend of Mickey, manufactured by Walt Disney.
Minusgreen gel a magenta gel used to take the green out of fluorescent light.
MIRED one million times the reciprocal of the Kelvin rating of a given light source. The MIRED scale is used to determine the color shift of a given gel when used with any source. Short for *microreciprocal degree*.
Mole-pin a 0.5 in. slip pin used as a distribution system connector.
MOS A scene filmed without recording sound.
Mountain leg the leg of a three-leg stand that extends to allow the stand to remain upright on uneven ground.
Mover an automated light fixture typically having motorized pan, tilt, beam focus, zoom, color, gobos, shutter, iris, and other features.
Multiline spectrum the spectral energy distribution graph of an HMI light. Instead of a continuous line across the color spectrum, the color makeup is created by numerous single spikes.
Musco Light a very powerful mobile lighting truck.
NABET National Association of Broadcast Employees and Technicians. Trade union.
Nanometer (nm) a unit of length used to measure the wavelengths of the colors of light. One nanometer equals one-billionth of a meter.
ND *see* neutral-density.
NEC National Electrical Code.
NEMA National Electrical Manufacturers Association. Defines such things as standards for connectors and ingress protection for electrical equipment in the United States.
Net a black honeycomb netting material sewn onto a rod frame that is used to reduce the intensity of part or all of a light's beam.
Neutral-density (ND) a gel or filter that reduces light transmission without altering the color of the light.
NFPA National Fire Protection Association.
Ni-Cad Nickel cadmium. A type of rechargeable battery chemistry.
Ni-MH Nickel-metal hydride. A type of rechargeable battery chemistry.
Nook light a small, lightweight open-face fixture that typically uses a double-ended bulb and a V-shaped reflector.
Offset a piece of grip hardware used to hang a light out to the side of a stand.
Ohm (Ω) a unit of electrical resistance equal to the resistance through which 1 V will force 1 A.
Opal a popular, thin diffusion.
Open-face light a fixture that has no lens, only a bulb mounted in front of a reflector.
Opto-isolator an optically isolated signal amplifier that reads and regenerates a DMX512 control signal and outputs it to a single output connector.
Opto-splitter an optically isolated signal amplifier that reads and regenerates a DMX512 control signal and outputs it to multiple output connectors.
OSHA Occupational Safety and Health Administration.
Overcurrent device a circuit breaker or fuse.
Overhead set a large frame with one of several types of material stretched across it, including a solid, single net, double net, silk, or griffolyn.
O-zone the open spaces between the perms, in the rafters of a sound stage. Only rigging grips are typically allowed to work in the O-zone using safety proper fall protection equipment.

PA *see* production assistant.

PAM (pulse amplitude modulation) solid-state electronics used to drive current-driven devices such as fluorescent lights and LEDs. PAM limits the current using high speed switching. At very high frequency, the current is allowed to rise to a set maximum and is then shut off.

Pancake a ¾ in. piece of plywood matching the dimensions of the large side of an apple box.

Paper method a method of calculating the amperage of 120 V fixtures by dividing the wattage by 100.

Parabolic reflector a reflector shaped like a parabola, giving it a focal point from which all light rays will be reflected outward in a parallel beam.

Parallel circuit the connection of two or more fixtures across the same conductors of a circuit such that current flow through each is independent of the others.

Parallels a small, easy-to-assemble scaffold platform.

PAR can A rugged fixture used often in rock-and-roll concerts. A PAR can is simply a PAR globe mounted in a cylindrical can that provides a slot for colored gel.

Party gel colored gels, also called *effects gel* or *theatrical gel*.

Patch historically, the process of physically connecting circuits to dimmers. Now usually refers to electronic assignment of dimmers to channels. *Patch* does not refer to the assignment of channels to cues or submasters.

Peppers a line of small, lightweight tungsten lights manufactured by LTM in sizes of 100, 200, 300, 420, 500, 650, 1000 W, and 20k.

Perms permanent catwalks near the high ceilings of sound stages.

Phantom load *see* ghost load.

Phase (1) An energized single conductor, usually ungrounded and never the neutral. (2) The positioning of an AC cycle in time, relative to the phases of the other hot legs. Most electrical services are either single-phase or three-phase services.

Photoflood a bulb, typically with a standard medium screw base that has a color temperature of 3200–3400 K.

Piano board originally, a portable dimmer switchboard or road board. This term has come to be used for many types of portable dimmer switchboards.

Pigeon plate a baby nail-on plate.

Pins any of several types of connectors. Mole-pins and *0.515* pins are single-conductor slip pins used on feeder cable. Three-pin connectors, commonly called *Bates connectors*, are also sometimes called *pins.*

Pipe clamp a clamp used to hang a light from an overhead pipe.

Pixel mapping software is used to map a video, graphic or other image onto an array of individual lights (typically RGB LEDs) in order to create a large display or graphic effect.

Plano-convex a lens that is flat on one side and convex on the other. Light comes from the flat side and converges or diverges as it passes though the lens, in proportion to the lamp's distance to the lens.

Plate dimmer a resistance-type dimmer commonly used with DC circuits.

Plusgreen gel a gel used to add green to lights to match their color to that of fluorescent bulbs.

Polarity the orientation of the positive and negative wires of a DC circuit or the hot and neutral wires of an AC circuit. A polarized plug cannot be plugged in with reversed polarity.

Pole cats lighting support equipment consisting of extendible metal tubes that wedge between two walls or between floor and ceiling to which lights can be mounted.

Power the total amount of work, measured in watts. The term is also generally understood as electricity, or juice.

Power/DMX an arrangement used by some accessory devices such as gobo rotators, and also some LEDs, that provides both a DMX512 signal and low-voltage power to the device on the same cable. Power/DMX typically uses a four-pin XLR in which the first three pins are configured to carry a DMX512 signal, and the fourth pin carries low-voltage power (24 V is typical).

Power factor in AC, the ratio of the actual or effective power in watts to the apparent power in volt-amperes, expressed as a percentage. Inductive loads cause the current to lag behind the voltage, resulting in a power factor of less than 100%.

Practical lamp a lamp, sconce, or fixture that is shown in the scene.

Prefocus base the type of lamp base.

Prelight or prerig to rig in advance. During production, the grip and electrical crew may form a second crew or bring in a second crew to work ahead, rigging the sets that are to be shot during the following days.

Preset of a dimmer console, a predefined set of intensities for a set of channels, stored in memory for later replay.

Primary colors— for light, red, blue, and green. When the primary colors of light are projected onto a white surface, the area where all three colors intersect theoretically make white light.

Prime fixture a focusable, open-face fixture.

Priscilla a silver lamé stretched on a frame and used to bounce light.

Producer the person who oversees the production of the film or television show from the very beginning (obtaining the script, finding the backing to produce the show) to the very end (selling the finished film in domestic and world markets). The producer is the ultimate authority on all money-related decisions and most others. Everyone on the production works for the producer.

Production assistant (PA) the bottom rung entry-level position in film production (although director is also often an entry-level position). A PA performs any number of tasks, including "locking up the set," calling for quiet before each take, distributing scripts and paperwork, running errands, attending to special needs of actors, director and producers, getting coffee, lending a hand with the assistant directors, and so on.

Programmer lighting control programmer. The operator of the lighting control console, especially moving light consoles and other advanced devices.

PSA public service announcement.

PWM (pulse width modulation) method of voltage control used in a vast array of electronic power supplies and dimming equipment. Pulse width modulation controls RMS voltage by altering the duty cycle.

R resistance, measured in ohms. *See* resistance.

Rag the cloth part of an overhead set.

Rain tent a tent to cover lights and electrical equipment in case of precipitation.

RDM remote device management. A control protocol that allows two-way communication between control console and DMX512-A/RDM devices.

Reactance (*X*) a measure, in ohms, of the opposition to AC due to capacitance (X_C) or inductance (X_L).

Receptacle a female connector or female mounting hardware.

Rectifier an electrical unit that converts AC to DC.

Redhead a 1k open-face fixture.

Reflected light meter a light meter that reads the amount of light reflected by the scene into the meter. A standard reflected meter has a relatively wide angle of view and averages the areas of light and dark to give the reading. *See also* spot meter.

Reflectors silver-covered boards typically used to bounce light, usually sunlight. Also called *shiny boards*.

Resistance (*R*) A measure, in ohms, of the opposition to current flow in a conductor, device, or load. In DC, volts ÷ amperes = ohms of resistance. For AC, see impedance.

Reverse phase dimmer a type of electronic dimmer, which employs an IGBT circuit to vary the duty cycle of each half-cycle by varying the point at which the circuit is switched OFF.

RGB LED LED having red, green, and blue emitters. Using additive mixing, a wide array of colors are possible.

Rheostat a resistance dimmer.

Rigging bible a set of diagrams showing the power layout of a studio's sound stages.

Rigging gaffer the gaffer in charge of designing and installing the cabling and electrical distribution for, and prelighting the set.
Rim a backlight that makes a rim around the head and shoulders of the subject from the perspective of the camera.
Ritter fan a large effects fan used to blow snow and rain and to give the appearance of wind or speed.
Safety a wire, chain, cable, or rope looped around the bail of a light to prevent it from falling should it come loose from its mount.
Sandbag a sand-filled bag used to stabilize stands and equipment by adding deadweight or counterweight.
Scale the minimum pay scale set forth by the labor union representing the crew or cast.
Scissor clip a device that provides a means of hanging lights from a dropped ceiling, such as those found in many modern commercial buildings.
Scoop a lighting fixture that consists of a large 1k or 2k bulb mounted in a reflector. Scoops are used for general area light.
Scosh a very small amount, as in "Flood it out a scosh."
SCR silicone-controlled rectifier**.** A type of AC dimmer circuit used by a forward phase control dimmer to vary the duty cycle by switching off the circuit at a (variable) point in each half-cycle.
Scrim a circle of wire mesh, which slides into the ears on the front of a fixture and reduces the intensity of the light. A single dims the light about a half-stop. A double dims it about one stop. A half-single or double affects only half of the beam.
Second team the stand-ins are actors used, in place of the real cast, as models during lighting, to line up shots, and to rehearse camera moves.
Secondary colors the colors formed by combining two primary colors. Also called *complementary colors.*
Senior a 5k incandescent Fresnel fixture manufactured by Mole-Richardson Co.
Series circuit connection of two or more devices or loads in tandem so that the current flowing through one also flows through all the others.
Service entrance the main panel board into which the power lines running to a building terminate.
Service electrical service. This term can refer to the types of circuits installed, for example, single-phase, three-wire service.
Shock the sensation or occurrence of an electrical circuit being completed through a person's body.
Short circuit unwanted current flow between conductors.
Show card thick card stock, usually white on one side and black on the other, used to bounce light.
Shutter in a motion picture camera, a butterfly-type device that spins in front of the aperture plate.
Shutters a device that is mounted at the front of a light to douse the light using Venetian blind-like metal slats.
Silicone spray a dry lubricant used on dolly track.
Silk silk fabric used to soften and cut the intensity of light. It is used in all sizes, from very small dots and fingers to very large 20 × 20-ft overheads.
Silver bullet a 12k or 18k HMI light manufactured by Cinemills Corp.
Sine-wave dimmer a type of electronic dimmer that creates no filament buzz (associated with phase control dimming) by electronically varying the effective voltage of a sinusoidal waveform.
Single-phase a single phase load is any load that is powered from one phase wire and the neutral, or two phase wires. Almost all lighting loads are single-phase. See also *three-phase*.
Sister lugs *see* lug.
Sky pan a large, soft light fixture used for general fill, comprising a 2k, 5k, or 10k bulb and a large pan-shaped reflector.
Slot the DMX512 control protocol provides 512 data slots in each universe. Each slot supplies a device with an 8-bit value (a number between 0 and 255), which may be used to control a parameter of that device.

Snoot a black metal cylinder or cone mounted on the ears of a fixture to narrow the beam.
Snot tape sticky adhesive substance used to attach gel to a frame.
Socapex commonly used to refer to 19-pin-compatible connectors, sometimes also called a multipin connector. Socapex is a trademarked name owned by Amphenol-Socapex, the original manufacturer. Multiconductor cable is commonly used for dimmer circuits, but may also be used for any function where six circuits are run in one cable.
Soft box a device used to create soft, diffuse light, typically having a diffusion front and solid sides to contain spill light.
Soft light (1) a light fixture with a large, curved, white reflector surface that bounces light onto the scene. (2) Light emitted from a relatively large diffuse surface.
Solid a black "rag" stretched on a frame and used to cut light.
Sound mixer the person who operates the audio recorder machine.
Space light a large silked cylinder that hangs above the set to create soft ambient illumination.
Spark a nickname for set lighting technician.
SPD spectral power distribution (graph).
Specular an adjective used to describe hard light emitted by a point source.
Spider box a cable splicing box used to join feeder cables.
Spot meter a type of reflected meter having a very narrow angle of acceptance used to determine the light value of a specific point on the set.
Spot a beam focused into a narrow, relatively strong beam of light.
Square wave a type of AC created by an electronic ballast that can be used to greatly broaden the window of flicker-free operation of HMIs.
Squeezer a dimmer.
Staging area the area on the sound stage or location selected as a temporary place to keep the lighting equipment and carts.
Start address the DMX512 address set on a the signal receiver which is the first DMX512 address a device will respond to. The device responds to the values of subsequent slots in accordance with its personality.
Stickup an extremely small, lightweight fixture that can be taped to the wall.
Stinger an extension cord; officially, a hot extension cord.
Stokes shift phosphors are used in fluorescent lights and LEDs to broaden color spectrum from a more monochromatic pump color. The Stokes shift is the difference between the pump color and the resulting spectrum after light energy bombards the phosphors.
Stop an f-stop or a t-stop.
Strain relief a rope tie used to reduce strain at the point at which a cable attaches to its connector.
Streaks and tips cans of hair color that are often handy for darkening reflective surfaces.
Strike (1) To dismantle a set or to take down and put away a piece of equipment. (2) When referring to an HMI, to *strike* the light can mean to turn it on.
Strobe light a light that creates short, bright, regular flashes of light at an adjustable speed.
Studio zone in California, the area within 30 miles of a specific point in Hollywood. Labor rules are different inside and outside of this zone.
Submaster a controller (usually a linear slider) on a dimmer board that allows manual control of groups, effects, cues, or channels.
Suicide pin an adaptor with two male ends.
System grounding the grounding of the service equipment and the current-carrying, neutral white wire to the transformer and to earth.
Taco cart a special cart that carries grip equipment, such as C-stands, apple boxes, wedges, mounting hardware, and grip expendables.

Tag line a line dropped from aloft and used to hoist equipment into a catwalk, green beds, or Condor.

Talent on-camera people and animals, usually actors, not necessarily talented ones.

T-bone a metal T-shaped base with a junior receptacle, used to place larger lights at ground level.

Termination on a DMX512 network, the last device in the chain of devices must be terminated using a termination plug or via a switch on the last (if so equipped). Termination is necessary to prevent signal reflections that can corrupt the signal data.

Three-fer a connector that provides three female connectors from one male connector.

Three-phase a three-phase power source creates alternating current in three leads—the AC cycle of voltage in each lead is a third of a cycle (120°) apart from the last. A three-phase power source may be used to power single-phase loads of different voltages by using two of the phase wires, or one phase wire and a neutral wire. A three-phase load in one that requires all three phase wires. Examples of three-phase loads used in lighting include some xenon ballasts, chain motors, Luminys SoftSun, and 480 V step-down transformers.

Three-riser a stand that has three extensions.

Throw the distance at which a fixture can effectively light a subject.

Tie-in the connection of distribution cables to a facility's service panel.

Titan a 350-A carbon arc light manufactured by Mole-Richardson.

Tracing paper thin, translucent paper used to white-out windows, also called 1000H.

Transformer a device with no moving parts and two or more insulated windings on a laminated steel core that is used to raise or lower AC voltage by inductive coupling. Volt-amperes into the primary coil and volt-amperes out of the secondary coil are the same, less the small current necessary to magnetize the core.

Tree a tall stand or tower that has horizontal pipes on which lights can be hung. Used a great deal in theater and concert lighting.

Triac a type of solid state dimmer circuit used in household dimmers, based on PWM control.

Trombone fixture-mounting hardware that hooks over the top of the set, drops down the set wall, is adjustable, and provides a baby or junior stud or receptacle to which a light is mounted.

Truss a metal structure designed to support a horizontal load over an extended span. Truss is used to support lighting fixtures aloft.

T-stop the aperture setting of a zoom lens after compensation for light lost in the numerous optical elements of the lens.

Tungsten color temperature a color temperature of 3200 K.

Tungsten halogen lamp a lamp designed to maintain an almost constant color temperature and a high lumen output throughout its life. The halogen cycle is a regenerative process that prevents the blackening of the inside of the bulb.

Turnaround the time between the time you go off the clock on one day and call time on the next.

Turtle stand a squat junior stand that enables a large light to be positioned at ground level.

Tweenie a 650 W Fresnel light manufactured by Mole-Richardson Co.

Twist-lock a connector for which the plug inserts into the socket and then twists, locking the plug to the socket.

Type W cable cable manufactured to meet the requirements of NEC Articles 520 and 530 regarding portable entertainment cable. It is abrasion-, oil-, solvent-, and ozone-resistant and flame-tested.

U-ground a standard Edison plug with a U-shaped grounding pin.

UL Underwriters Laboratories. An agency that tests electrical equipment. A qualifying piece of equipment is referred to as "UL listed".

Ultraviolet (UV) the wavelengths of light below the shortest visible wavelength. UV-A is black light. UV-B radiation can cause skin burns and eye damage, as well as skin cancer, if not filtered.

Unilux a manufacturer of strobe lighting equipment that can be synchronized to a motion picture camera shutter.

Up-fade the portion of a fade that involves only channels that are increasing in level.

UPS uninterruptable power supply. A power supply used for powering mission-critical equipment, such as a control console, so that if the power supply is interrupted (the power cord accidentally gets pulled out), the UPS will continue to supply power via battery and sound an alarm.
USITT United States Institute for Theater Technology. The body that created the DMX512 system.
UV *see* ultraviolet.
V *see* volt.
VA *see* volt-ampere.
Variac an AC autotransformer dimmer—a type of variable transformer that can vary voltage below and above line voltage.
VEAM connector VEAM Litton is a manufacturer of connectors, including multipin HMI head feeder connectors and single-conductor feeder cable connectors.
Velum *see* tracing paper.
Visqueen plastic material used to protect equipment from precipitation.
Volt (V) a unit of electrical force. One volt is required to force 1 A of electricity through a resistance of 1 Ω (ohm).
Voltage drop the difference in voltage between two points in a circuit due to the intervening impedance or resistance.
Volt-ampere (VA) voltage times amperage. In DC, volts × amps = watts, but in AC, inductance and capacitance in the circuit may introduce reactance, causing a discrepancy (power factor) between watts and volt-amperes.
Voltmeter a meter used to measure voltage potential between two points in a circuit.
W *see* watt.
Wall sled a fixture-mounting device that hangs from the top of the set wall and rests against the wall.
Wall spreader hardware that mounts to either end of a piece of lumber, creating a span from one wall to another from which lights can be hung.
Watt (W) a unit of electrical power, the product of voltage and amperage.
Wedge a triangular wooden block used to level dolly track.
Western dolly a large flatbed camera platform with large inflated tires that steer at one end. A western dolly can be useful for moving lights and cable.
Wiggy a continuity or resistance-testing device.
Wireless DMX a system of transmitters and receivers used to transmit a lighting control signal using radio waves in the 2.4 GHz range.
Wrap the end of the work day. The process of taking down lights and coiling cable that begins after the last shot of the day has been completed successfully.
Wye-connected system a common type of three-phase transformer arrangement. On a 208Y/120 system voltage reads 208 V between any two of the hot legs and l20 V between a hot leg and the neutral white leg.
Xenon lights an extremely bright type of arc discharge light that has a color temperature of 5600 K. Because the arc is very small, the light can be channeled into a very narrow shaft of extremely bright light.
Y-1 a type of gel that converts a white carbon arc to normal daylight color balance.
Yoke *see* bail.
Zip cord two-wire, 18-AWG electric lamp cord.
Zip light a small soft light.
Zone system Ansel Adams's system of 11 gradations of gray from pure black to pure white. The zones are numbered in Roman numerals from 0 to X. There is a one-stop difference from zone to zone.

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Companion Web site

The book now has a companion Web site, which includes many new articles on advanced topics that could not fit in this volume. It also includes archived material that appeared in previous editions, photos, and helpful links.

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